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THE GEOGRAPHY OF THE GRAY SEAL

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The gray seal, *Halichoerus grypus* (Fabricius), although it inhabits the coasts of the temperate North Atlantic within easy reach of large centers of human population, is still a relatively little-known species of mammal. In the British Isles it was initially confused with the bearded seal, *Erignathus barbatus*, and, as recently as 1935, Salmon pointed to further confusion with the harbor seal, *Phoca vitulina*. In eastern Canada, its true status was obscured for even longer. In the present review, I have attempted to survey the known distribution of the species, to explain some of the outstanding features of this distribution and to relate them to some characteristics of the biology of the gray seal which do not appear to have attracted the attention they deserve among zoologists. The literature cited represents only a fraction of that consulted and, in particular, the summaries of existing distribution and breeding seasons are based on many more authorities than those actually quoted. I am indebted to Professor H. N. Barber and Dr. H. D. Fisher for reading and commenting upon the manuscript. In addition, Dr. Fisher has allowed me access to unpublished material relating to Canadian gray seals.

PRESENT DISTRIBUTION

The known breeding range is shown in Fig. 1. There appear to be three distinct population groups, separated today by wide gaps in the total range of the species and by differences in the breeding season.

The first group has its headquarters in the Gulf of St. Lawrence. Fisher (1950) summarized its distribution as "north shore of Anticosti Island, around Mingan Islands, along the south shore of St. Lawrence estuary, Magdalen Islands, Northumberland Strait, Cape Breton Island on west and north, east coast of Nova Scotia, Miquelon Island, Sable Island, Grand Manan." According to Millais (1904) there was a large colony on one of the Grey Islands off northeastern Newfoundland, but he said that the species was only a rare visitor to the other coasts of that island. While the southern limit of the breeding range in the West Atlantic can be fairly confidently placed, it is much more difficult to assess how far north the gray seal extends as a breeding species. Millais quoted inconclusive evidence of its occurrence to 58°N along the Labrador coast, but so far no evidence of breeding has been forthcoming. A similar doubt exists about the status of the species in Greenland, although this is the type locality for *Halichoerus grypus* (Fabricius, 1791). An old record exists for Disco Bay, about 1300 miles north of Newfoundland (Brown, 1868), and this frequently has been quoted as evidence of the presence of the species in Greenland, although it was based on a skull which was lost shortly after being obtained and there appear to be no subsequent records. No breeding

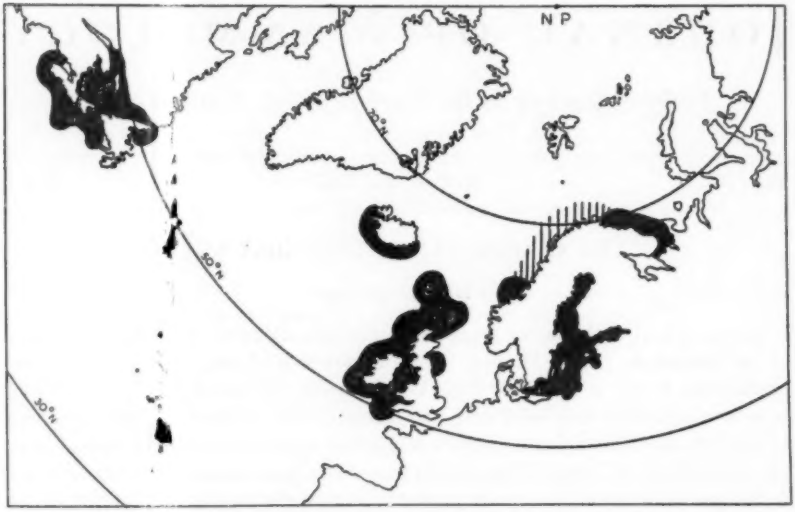


FIG. 1.—The breeding distribution of the gray seal. The known distribution is shown in black; in the hatched area, breeding is probable but not recorded.

colonies have been found and the gray seal is not mentioned by modern writers on Greenland mammals. Saemundsson (1939) stated that the species was absent from Greenland. On the other hand, neither the Labrador nor the Greenland coasts have been sufficiently explored zoologically for any dogmatic statement to be made, and the long delay in the full recognition of the species in eastern Canada should be a sufficient warning in this regard. Even so, present evidence indicates that, at most, the species is only a straggler to Greenland and the unqualified inclusion of Greenland in its range by some authors is misleading.

The second population exists in the East Atlantic and has its headquarters in the British Isles. Breeding colonies extend from southwestern England northward along the Welsh and Irish coasts and the west coast of Scotland to the Orkney and Shetland Islands, while an isolated but large colony is based in northeastern England. The distribution of British colonies is shown in Fig. 2. To France, Holland, northwestern Germany and the west coast of Jutland the species is an uncommon visitor (Legendre, 1947; Ijsseling and Scheygrond, 1943; E. Mohr, personal communication; Degerbøl, 1935).

From Scotland, the breeding range extends northward in two directions. First, it extends by way of the Faroes (Degerbøl, 1940) to the south and west coasts of Iceland (Saemundsson, 1939). This is the nearest point of contact between the East Atlantic and West Atlantic groups, the distance between western Iceland and Newfoundland or Labrador being about 1,500 miles. Any colonies discovered in southern Greenland would roughly halve this figure.

The second northward extension of range is along the North Atlantic Drift current and around the Norwegian coast to the White Sea entrance. The distribution of breeding colonies in Norway is poorly known. The large colony described by Collett (1881) at the Fro Islands off Trondheim Fjord is the only one documented and information from Dr. Erling Sivertsen relayed by Dr. Erna Mohr indicates that this is still the only known colony. Collett did, however, mention probable breeding colonies at Vigten, Melö and Troenen to the north. There is no evidence at all for breeding to the south of Trondheim, although general faunal works (Collett, 1912; Wollebaek, 1927) imply that the species occurs on all the coasts of Norway. Sim-

ilarly, there is no evidence of breeding on the west coast of Sweden. On the other hand, breeding along the Murman Coast is well attested and Russian workers have recorded and studied breeding colonies in the neck of the White Sea (Bobrinskii *et al.*, 1944). Eastward

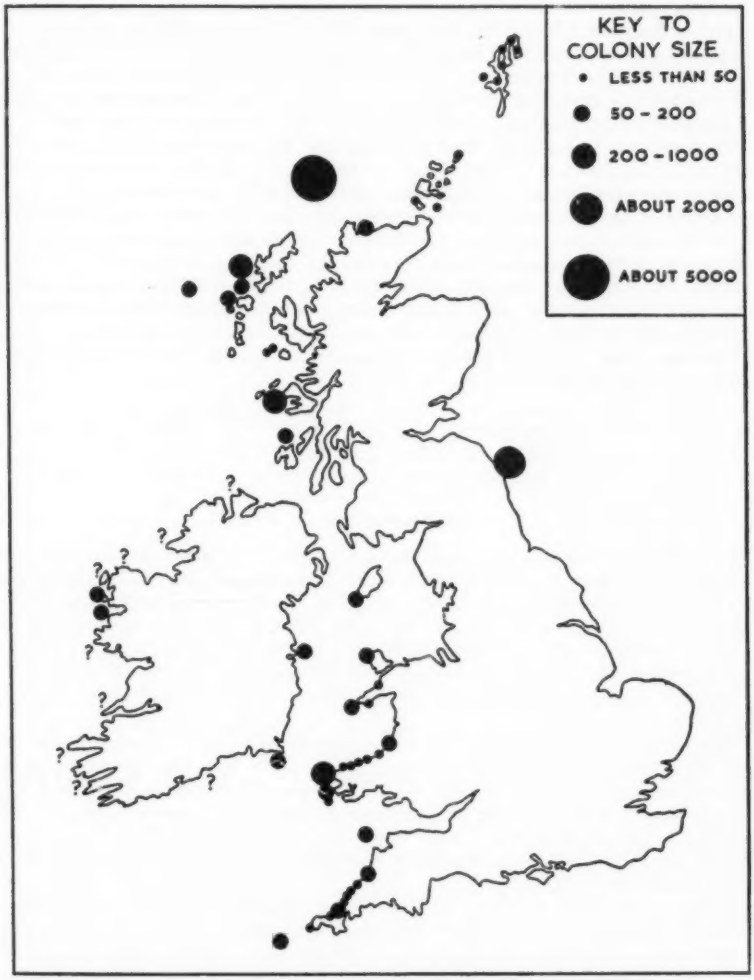


FIG. 2.—Breeding colonies in the British Isles. The information for England, Wales and eastern Ireland is probably complete and accurate. In western Ireland, the question marks indicate districts where I have evidence of breeding but no information on either the exact locality or the size of the colony. In Scotland, a very few small colonies may be overlooked. The distribution in the Orkney and Shetland Isles is repeated from Darling (1947) and I have no direct information on the size of colonies, all of which are believed to be small.

from here is another region of doubt. There is evidence of occurrence in the Barents Sea as far as Novaya Zemlya (Hjort and Knipowitsch, 1907; Smirnov, 1908; Ognev, 1935) but no evidence that the seals seen here are other than visitors from the White Sea or Murman districts. At Spitzbergen, Bear Island and Jan Mayen, the gray seal is unknown and the single record for Franz Josef Land (Zalkin, 1936, quoted in Legendre, 1947) is probably in the same category as that from Atlantic City, New Jersey, U.S.A. (Goodwin, 1933).

The third and last group inhabits the Baltic Sea. There is a large literature dealing with the Baltic gray seal, but much of it is very inexplicit as far as breeding localities are concerned. This is probably because the species appears to breed almost entirely on ice floes in the Baltic and presumably exact localities are difficult to give. It is clear, however, that the most important breeding areas are in the Gulf of Bothnia and that, generally speaking, the species becomes less numerous as a breeder to the south. It is found in the Gulf of Finland and along the coasts of eastern Sweden and of Estonia, Latvia and Lithuania. Millais (1904) quoted breeding at Gotska Sandö near Gotland. The breeding range in the Baltic is gradually shrinking and although islands in the Kattegat were formerly used, Rodsand to the south of Lolland now seems to be the only possible Danish site (Degerbøl, 1935). According to Dr. Erna Mohr (personal communication), the gray seal no longer breeds on the German coast and seals which appear there probably breed on the ice near Bornholm. Either Rödsand or Bornholm is therefore now the nearest breeding point to the range of the East Atlantic group.

The normal range of sea temperature and salinity encountered by seals of the three groups is given in the table below:

Group	*Temp.*, °F	*Salinity*, °/₀₀
West Atlantic	30–63	28–33
East Atlantic	34–63	30–36
Baltic	32–65	3–10

ABUNDANCE

The world numbers of the gray seal are very small. It is far less abundant than most species of pinnipeds, but it is by no means as rare as many writers claim. It has been called the rarest seal in the world, although it is easy to think of at least six other species whose numbers must be less. In all parts of its range, except perhaps the Baltic, its true status has remained hidden until relatively recently and new breeding areas and colonies may yet be found. Even so, its total numbers remain small and, because of its vulnerability at the breeding season, it is probable that, if it had proved important commercially, it would by now be extremely rare or even extinct.

Fisher (in press) gives the total number of seals in the West Atlantic group as more than 5,000 and provides some details for individual colonies. The largest breeding congregation seems to be in Northumberland Strait at Amet Island, where Fisher estimates the adult population as between 2,400 and 3,000. Other colonies are considerably smaller, but several, such as those at Deadman Island in the Magdalens, Sable Island and Great Miquelon, are some hundreds strong. Fisher's figure of 5,000 is essentially a minimum and the actual total is probably much more.

Numbers in the East Atlantic group are better documented. I have attempted an estimate of total numbers for the British Isles by listing minimum and maximum population figures for each of the colonies shown in Fig. 2, and puts this at between 11,000 and 15,000. Greatest doubt concerns the numbers at North Rona, which is probably the largest single colony of the species in the world, and those of scattered small colonies along the west coast of Ireland. In the Faroes, there are many inhabited breeding places and the gray seal is "becoming more frequent" (Degerbøl, 1940). According to Saemundsson (1939), the species is fairly common in southern and western Iceland, although rare elsewhere. He implies that about 350 young and about 100 other gray seals are killed annually.

Collett (1881) gave the population of the Fro Islands colony in Norway as 500 to 600, but

there is no other information. Hjort and Knipowitsch (1907) mentioned a great decrease in numbers along the Norwegian coast and said that the gray seal was only found in small numbers in the Russian section of its range. This was confirmed by later writers (Ognev, 1935; Bobrinskii *et al.*, 1944). Norway therefore again remains the major unknown factor, but it would be surprising if the total for the East Atlantic group proved to be more than double that for the British colonies.

In the Baltic, an idea of relative abundance must be gained from records of numbers killed rather than from totals of individual colonies, which do not appear to be available. In both Sweden and Finland, the gray seal is sufficiently abundant to be regarded as a noxious animal and has, for a long period, had a price upon its head. Mohr (1952) quoted figures of 2,457 gray seals killed in Finland in 1909, about 850 in Sweden from 1923 to 1925, 607 in Denmark from 1919 to 1926, and 381 in Germany from 1912 to 1920. According to Eckerbom (1948), about 1,500 gray seals were killed in Sweden every year during the 1930's and about 4,000 a year in other Baltic countries. He stated further that many hunters were of the opinion that there were just as many seals as ever.

Recently, an attempt at an estimate of world gray seal numbers has been made by Lockley (1954), who gives the following figures: Gulf of Bothnia, 5,000; Western Baltic and Kattegat, 100; Norway, 400; Faroes and Iceland, 3,000; Gulf of St. Lawrence, 5,000; British Isles, 20,000. With the exception of those for Norway and the British Isles, the figures are admittedly guesses. The figure for Norway assumes that the Fro Islands colony is the only one, and that for the British Isles is based on estimates of calf production at individual colonies. The Russian population is ignored, but this is unlikely to affect the grand total seriously and the major difficulty arises in estimating the Baltic population. Lockley quotes annual figures of gray seals killed in Sweden from 1943 to 1953 which show that, apart from the year 1944 when there was a kill of 1,345, the annual total varied between 615 and 850 until 1949, after which there was a marked drop which has continued since, although the number of seal hunters has remained generally the same. His figure of 5,000 for the Baltic group takes account of this apparent drop in total numbers, but I am inclined to think that this figure may be a considerable underestimate. If Eckerbom (1948) is correct in saying that the Swedish kill in the 1930's was little more than one quarter of that for the Baltic as a whole, it seems that the figures from Sweden can only give a partial view of the total picture. It is not intended to argue too closely from the figures which have been quoted, but it is clear that, at least until 1949, the gray seal was by no means a scarce animal in the Baltic Sea. A species which could suffer such losses and retain approximately its population level must have existed in tens of thousands. During most of the present century, the population of the Baltic group must have been comparable to, and may even have exceeded, that of the East Atlantic. Whether there has been such a spectacular decrease as has been postulated by Lockley remains an open question until further evidence is forthcoming, especially from the eastern shores of the Baltic.

In spite of the several uncertainties, some tentative conclusions may be reached. The population of the East Atlantic group is probably slightly larger than that of the Baltic group, and both are larger than the West Atlantic group. In each of the three groups there is one relatively large breeding center where several thousands of adults congregate in the breeding season. In the West Atlantic this is in Northumberland Strait, in the East Atlantic it is at North Rona, and in the Baltic it is in the Gulf of Bothnia.

The total world population of the gray seal must be about 50,000.

MOVEMENTS

The following comments can be made about movements of seals within the East Atlantic group. The young gray seal spends the first two years of its life at sea and appears not to return to the home colony during this period. An exception to this rule is a small and varying number of individuals which remain about the breeding grounds from birth. The extent of

the young seals' wanderings during these years is at present being worked out in Britain through recently instituted tagging schemes (Telfer and Watt, 1953; Hewer, 1955). Distances of about 400 miles have already been established and there is considerable overlap of range from different colonies or even groups of colonies. Natural mortality drops so sharply after the first two years that it is unlikely that present tagging schemes will reveal much about the movements of older seals unless recourse is had to slaughter.

Seals aged two years and upwards attend at the breeding grounds at least once a year, during the breeding season, and at some colonies there is evidence of a second congregation about March, which may be associated with a "false rut." In the time between these congregations, dispersal takes place to a greater or lesser degree. The degree of dispersal seems to depend upon the size of the breeding colony and the amount of food available in its vicinity. At small colonies with a population of about 100 or less, seals may remain at or near the breeding grounds throughout the year. At larger colonies, dispersal must take place in order that adequate food supplies may be found. Little is known about the nature of these dispersals, but it seems probable that, as in the case of yearlings, there is considerable overlap outside the breeding season between colonial populations. However, evidence adduced as to the degree of intercolonial variation which takes place in behavior, development and morphology strongly suggests that there is a well-marked homing tendency and that colonies or groups of colonies remain more or less genetic entities.

This general picture would seem to be equally true for the Baltic. The largest congregation for breeding is in the Gulf of Bothnia and, after the breeding season, seals from here disperse southward over the Baltic; but within the area of dispersal are small colonies where the seals are more or less resident. Eckerbom (1948) quotes Harstena in Sweden as an example of one of these small colonies where about 50 calves are born yearly.

As yet, little is known about movements within the West Atlantic group. Fisher (personal communication) informs me that young seals appear to disperse in a radial fashion, but it appears that there may be some organized and well-defined movements of older seals. For instance, a congregation of about 500 frequents the Miramichi estuary outside the breeding season (Fisher, in press).

THE ORIGIN OF THE THREE GROUPS

The gray seal is a seal of temperate waters and its general distribution in the North Atlantic area is more southern than any pinnipeds except *Phoca vitulina* and the tropical Monachinae. There is no evidence that it has ever occurred elsewhere and its possibly nearest fossil relative, *Gryphoca*, has been found in Belgium (Van Beneden, 1876). If we assume that it has occupied the temperate North Atlantic during and since the Pleistocene, then its present discontinuity of range can be explained in terms of the known sequence of events and the general picture of Pleistocene biogeography which is gradually being revealed (see, for instance, Flint, 1947; Deevey, 1949). In common with other organisms, the gray seal must have been subjected to the alternate expansion and contraction of the ice sheets. Fossil evidence is lacking, but there are many records of other pinnipeds in Pleistocene deposits well to the south of their existing ranges on both sides of the Atlantic (e.g., Hay, 1923; Harlé, 1913) and it is reasonable to suppose that the gray seal extended little further north at such times. We can visualize the species as occupying the Labrador-Greenland-Iceland-Norway area in interglacials and, during glacials, being pushed south along the coasts of North America and Eurafrica, so that two discrete populations arose, now represented by the West Atlantic stock on the one side and the East Atlantic-Baltic stock on the other. The last such separation must have taken place at least as long ago as the last glaciation (Würm-Wisconsin) and there is no evidence as to whether, since then, the ranges of the two stocks have at any time rejoined. The northwestward extension of range of the East Atlantic group from the British Isles to the Faroes and Iceland and the northeastward extension to Norway, the Murman coast and the White Sea probably represent the lines of spread northward with the amelioration of climate

in post-Pleistocene times. The West Atlantic and East Atlantic groups appear to be separated today geographically by about 1,500 miles and physiologically by different breeding seasons.

The separation of the East Atlantic and Baltic groups must have come at a much later date and it is possible to postulate the history of this separation with a greater degree of certainty, since the post-glacial history of the Baltic Sea is relatively well known. At the height of the last glacial period, an ice sheet covered the present sea and the Baltic first emerged as a lake with the retreat of the ice. With further retreat and a rise of sea level, connection was made with the Atlantic across the lowlands of central Sweden, at present occupied by Lakes Vänern and Vättern. The Baltic Ice Lake gave way to the Yoldia and Rhabdonema Seas. Subsequently, a rise of land relative to the sea led to the blocking of the Atlantic connection and the formation of the Ancylus Lake, which lasted until a new Atlantic connection was established and the Littorina Sea was formed. This new connection was through the present Kattegat and the Danish Sounds and has since become narrower and shallower so that the present connection is by straits only a few miles wide.

Clark (1946) presented archaeological evidence for the existence of the gray seal in and around the Baltic since the Pleistocene. There are signs that it was being hunted by Mesolithic peoples at the southwestern end of the Ancylus Lake and remains have been recorded by Munthe (1895) from Ancylus shores at Skattmansö in Uppland. If the species was present in the Ancylus Lake, then it follows that it must have entered during the existence of the Yoldia, or more probably the Rhabdonema, Sea. Existing chronologies for post-Pleistocene Scandinavia enable us to date this quite firmly at about 9,000 to 10,000 years ago. The subsequent separation of the East Atlantic and Baltic populations took place with the formation of the Ancylus Lake about 9,000 years ago. The Ancylus Lake may have lasted up to about 3,000 years before the Littorina Sea was formed and the gray seal spread into the Kattegat, where its remains have been found in abundance at Neolithic sites. In the absence of any evidence for present or past breeding in southern Norway, it is impossible to say whether the ranges of the two stocks again met, but by this time differentiation of the breeding season had probably taken place, so that they were effectively isolated physiologically even if not geographically.

Since the Neolithic, the geographical isolation of the Baltic stock has become gradually more pronounced as breeding grounds in the Danish islands, such as Anholt and Hesselö, have been abandoned. It is possible that the ranges of the East Atlantic and Baltic stocks do overlap outside the breeding seasons, but it appears now that at least 700 sea miles separate the nearest breeding grounds of the two groups.

Figs. 3–7 attempt an illustration of the sequence of events postulated above. Although largely hypothetical, this sequence has a high degree of probability and takes account of the original unity which must have existed within the species, the present-day division into three well-defined groups, and the succession of geological events which must have had an effect similar to that suggested.

THE PROBLEM OF THE BREEDING SEASON

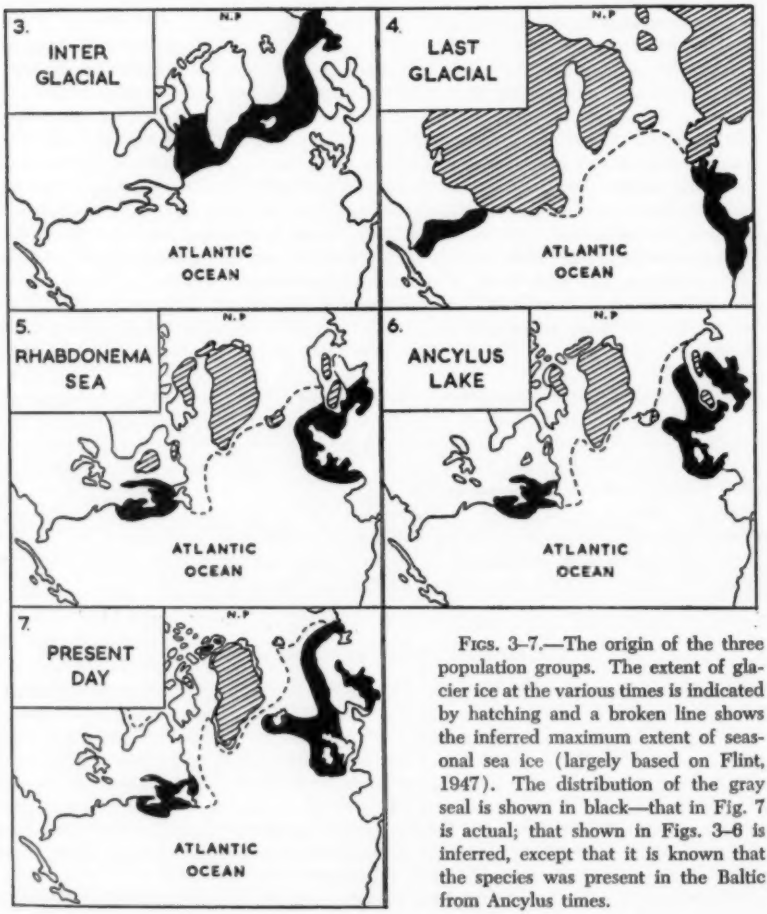
The fact that the gray seal of the West Atlantic had its breeding season in late winter or early spring appears to have been first noted by Gilpin (1874) who stated that the large seal of Sable Island "whelped in February or March." This did not come to the attention of Allen (1880), and Millais (1904) records how, when he was told that the gray seals of Newfoundland bred in spring, he thought his informants had confused that species with the bearded seal. The true state of affairs was not generally recognized until the work of Fisher in postwar years (Fisher, 1950). The main breeding month appears to be February. Gilpin gave February or March for Sable Island, and Fisher gives January and February for eastern Canada, although he says births occur chiefly in February.

In the Baltic, all accounts agree in giving February and March as the season of parturition

and, apart from a possible tendency towards later breeding in the north, there is little or no regional variation.

The East Atlantic gray seal differs markedly from seals of the other two groups and breeds in autumn. It differs also in that the breeding season may be spread over a much longer period—from July to December—and starting and finishing dates tend to vary much more between individual colonies. An examination of available information shows, however, that the effective breeding season is September and October in all except one colony and the great majority of young are born in these two months. The exception is the colony at the Farne Islands in northeastern England, where November is the important month and breeding extends from the fourth week in October to the third week in December (Telfer and Watt, 1953).

Certain authors (for example, Degerbøl, 1935; Mohr, 1952) seem to have interpreted these



FIGS. 3–7.—The origin of the three population groups. The extent of glacier ice at the various times is indicated by hatching and a broken line shows the inferred maximum extent of seasonal sea ice (largely based on Flint, 1947). The distribution of the gray seal is shown in black—that in Fig. 7 is actual; that shown in Figs. 3–6 is inferred, except that it is known that the species was present in the Baltic from Ancylus times.

differences in the breeding season as a cline, and it is still possible that this is the case. Breeding colonies may come to light in southern Norway and western Sweden or in Greenland and Labrador in which the breeding season is intermediate, or such colonies may have become extinct so that the present break is of relatively recent origin. But indications are that this is unlikely. There is a great degree of homogeneity within the groups and no sign of a cline between, for example, Britain and Iceland or Britain and Norway. In the Baltic the season seems to be very similar in the Gulf of Bothnia and in Denmark, while equally, in the West Atlantic, the breeding season seems to be uniform everywhere. A possible indication of a cline is provided by the late breeding colony at the Farnes, but this is contradicted by the Norwegian colony near Trondheim, which by sea is equally close to the Baltic group and in which the season is earlier. It would be a considerable coincidence if, toward either end of the supposed cline, the breeding colonies which demonstrate such a cline have not yet been found or have disappeared.

The question of how the differences in breeding season came about is relevant to the history of the three groups. Broadly, there appear to be three possible solutions to the problem. The first is that which seems to be generally taken for granted by the few writers who have remarked on the problem. It assumes that the East Atlantic gray seal is still holding to the original environment and breeding season, while the West Atlantic and Baltic groups have become adapted in some degree to life in seas which are generally less saline and are subject to extensive freezing of the surface in late winter and early spring. It is difficult to resist the conclusion that there is some connection between the late winter and early spring freeze-up in the Baltic and the Gulf of St. Lawrence and the late winter and early spring breeding season in those regions. The suggestion that the breeding season there is an adaptation to life in contact with ice has been made (for example, by Eckerbom, 1948) but no explanation seems to have been offered. In neither region does ice prevent breeding on rocks or sandbanks in the autumn months. If there is any adaptive significance in the different breeding seasons, then it is probably connected with the mortality among the young in the first few months of life. Mortality during this time is normally heavy. It would be considerably increased if the young, born in autumn, had almost immediately to contend with an ice-covered sea. Calves born later on top of the ice would be at an advantage and survival rates would be considerably increased if they took to the sea with the melting ice of spring.

In the case of the Baltic gray seal, it is not difficult to put forward an explanation of how contact with ice was forced upon the species. The Rhabdonema Sea was much more open to the Atlantic than the modern Baltic and was presumably influenced by the relatively warm North Atlantic Drift which must have had the same effect in inhibiting ice formation as it has today along the Murman coast and the White Sea entrance. It is probable that the seals could have established themselves as autumn breeders on rocks or sandbanks, at least in the southern part of the sea. The succeeding Ancylus Lake, on the other hand, was cut off from oceanic influence and was less saline, so that ice formation must have been markedly more intensive and extensive, even though atmospheric temperatures were by this time higher. When we turn to the West Atlantic, explanations become much more difficult. Here, with the retreat of the Laurentide ice sheet, the sea invaded the St. Lawrence lowland and the Champlain Sea possibly extended to include present Lake Ontario. Its successor, the Ottawa Sea, was smaller and reached about as far as the city after which it was named. According to the chronology of Antevs (1939), it was, in its later stages, contemporary with the Yoldia Sea of Scandinavia. It is probable that the gray seal was an inhabitant of this sea, as was *Phoca vitulina* (Hay, 1923), but there is no evidence that the St. Lawrence water body was ever isolated from the Atlantic and the deep St. Lawrence trough has been a permanent feature, at least since the middle Pleistocene. It is hard to see how the West Atlantic gray seal could have been forced into contact with ice, and this is the major weakness in the first of the three solutions to the problem. On the other hand, there is some evidence to suggest that seal species in the colder western parts of both the Atlantic and the Pacific become markedly more

adapted to contact with the ice than do those in the warmer eastern parts. In the case of *Phoca vitulina*, the other boreal species, the West Atlantic race, *concolor*, moves well into the subarctic of eastern Canada, while the East Atlantic race, *vitulina*, has no normal contact with ice. Similarly, in the Pacific, the western race, *largha*, has much more contact with ice than *richardii* on the eastern shores. According to Doutt (1942), *concolor* breeds on ice in Hudson Bay and according to Wilke (1954), *P. vitulina* not only breeds on ice in the Okhotsk Sea, but has also altered its breeding season to February and March.

The second solution would postulate that the gray seal was originally a seal of the pack ice and that the Baltic and West Atlantic groups have retained the original environment and breeding season. This, of course, involves the difficulty of accounting for the change in habitat of the East Atlantic group and of explaining why it has not followed the pack ice northward. It is also necessary to account for the change in the breeding season, and this seems particularly difficult since parturition in early spring would surely be advantageous from a survival point of view. This explanation has the advantage, however, that other pinnipeds give birth in spring or summer, so that the late winter and early spring breeding season is nearer to the norm than the autumn season of the East Atlantic gray seal.

The third possibility is that all three groups have deviated from the original breeding season, which may have been in spring or summer as in other pinnipeds. This drift may be to some extent random and not closely tied to the differences in habitat which have arisen. Some such drift in the breeding season, whether adaptive or not, does occur in other seals. The harp seal, *Phoca groenlandica*, breeds in three distinct population groups which have developed small but significant differences in the date of parturition (Sivertsen, 1941). The Farne Islands colony in England provides evidence of some such drift within one of the three main groups of the gray seal itself. The breeding peak here is almost two months later than in other colonies of the East Atlantic group.

Too little is known about the physiology of reproduction in the gray seal for more light to be thrown on this problem of the breeding season, but two phenomena may be suggested as particularly worthy of future investigation, since they may have a connection with the problem which is at present not apparent. These are the "false rut" and the delay in implantation of the ovum, neither of which has been proved for the gray seal, although by analogy with other species, it is very likely that they exist. Selby (1841) thought that the seals of the Farnes mated in February and, on Ramsey in 1947, I was told that mating took place in March, although it is clear that at both Ramsey and the Farnes, effective mating takes place in autumn, two weeks after the birth of the young. Mohr (1942) summarized evidence of "false rut" in the pinnipedia as a whole.

INTER-COLONIAL AND INTER-GROUP VARIATION

It may be appropriate here to summarize briefly the differences which have become apparent to date between the gray seals of the three major groups and between those of individual colonies or groups of colonies within these major groups. Three headings—behavior, development and morphology—will be used.

Behavior.—Certain of the more important differences in behavior are directly correlated with the differences in habitat between the three groups. The seals of the West Atlantic and Baltic give birth on the ice or on shore; those of the East Atlantic do so on shore and do not normally come into contact with a frozen sea. Presumably, therefore, they do not possess such techniques of living beneath the ice and keeping open breathing holes as belong to the Baltic gray seals. Outside the breeding season, there seems to be a difference in choice of hauling-out sites. A survey of the literature suggests that the Baltic and West Atlantic seals are significantly more liable to haul out on sand and mud banks than are those of the East Atlantic, which are largely, but not exclusively, confined to rocky shores.

Within the major groups, there is considerable variation in breeding behavior, some of which has been summarized previously (Davies, 1949). On some Scottish islands, breeding

seals come up well above high water mark and stay there for the duration of parturition, lactation and mating. The bulls take up territories on land and copulation takes place there. The territories of harem bulls form a honeycomb pattern. At all other stations in the East Atlantic, the breeding seals stay generally between tide marks, come little above high water level and stay more or less in contact with the sea. Bulls may take up territories on the beach or even in the sea and copulation may take place in the sea or on shore. The territories of harem bulls form a linear pattern along the shoreline. In the British Isles and at the Faroes breeding takes place commonly on beaches at the head of sea caves. Such colonies are difficult to detect and may be more numerous and widespread than is supposed. The degree of independence of land exhibited by breeding adults is correlated with precocity in the young.

Other differences of behavior, unconnected with breeding, exist. The seals of the Ramsey colony, in Wales, have developed a method of progressing overland on their sides which does not seem to have been noted elsewhere.

Development.—Important differences between British colonies in the development of the young have been found, and these generally relate to the greater precocity of seal calves in southern Britain as compared with those in northern colonies. The occurrence of a partial prenatal molt in some seals at Ramsey has been recorded and, although this phenomenon has been looked for in other British colonies, it has not yet been discovered. All stages of the molt seem to be accelerated in the southern British colonies and the period of time spent ashore by the young is correspondingly shorter. (For details see Davies, 1949).

Information from the Baltic is not sufficiently detailed to invite comparison, but accounts of Baltic seals suggest that the rate of development on the ice is similar to that at those Scottish colonies where the seals proceed to give birth well inland.

An interesting difference between the Baltic and East Atlantic stocks may lie in the stage at which the permanent dentition is acquired. Broch (1914) recorded gray seals in the Baltic shedding their milk teeth soon after birth, whereas in British gray seals they appear to be resorbed before birth. The calf is born either with no teeth showing or with permanent teeth just through. Fisher (personal communication) informs me that West Atlantic gray seals are born with the permanent dentition just through and further investigation of Baltic young seems necessary.

Morphology.—The question arises as to whether, if three well-marked population groups can be defined, any recognizable morphological differences have developed. The gray seal varies in coat color more than most other mammals and individuals in the same colony may differ from one another remarkably in this respect. Combinations and shades of gray, black, brown, cream and white occur in different patterns. Although this color variation has not been adequately studied, two general conclusions may be drawn. First, the coat color of females is much more uniform than that of males and throughout the range of the species the basic coloring is light gray ventrally, a darker gray dorsally with darker irregular blotchings on all surfaces. Second, while the range of variation in males is very much greater, some color varieties are confined to and appear characteristic of certain colonies (Darling, 1947). Whether similar variations in color can be detected between the three major population groups cannot be assessed from existing literature, but the available evidence suggests that coloration in the West Atlantic and Baltic stocks is much more uniform in the case of both males and females and adheres more closely to the normal gray coloration described above.

From time to time, specimens of *Halichoerus* are noted in which the ear pinna is abnormally well-developed. This tendency occurs in both the Baltic and East Atlantic stocks (Thienemann, 1931; Pocock, 1933) and in the colony at the Treshnish Isles, in Western Scotland, the male seals are all notable for the development of the external ear (Darling, 1947). Fisher (personal communication) says that the ear pinna in Gulf of St. Lawrence seals is fairly prominent, especially in the case of big bulls. He has noted no colonial differences.

There remains the question of osteological differences. In common with those of other

pinnipeds, gray seals' skulls exhibit so much variation with sex and age that several large series with details of sex and body length would have to be accumulated before any valid examination could be made. To date this has not been attempted. Some suggestions have been made, however, and Degerbøl (1940) mentioned the possibility that the breadth of the rostrum, measured vertically above the middle of the hindmost molar, is narrower in Baltic gray seals than in those of the East Atlantic. Supernumerary teeth are common in seals from both these groups and, in particular, a sixth molar is sometimes present.

It would seem that differences of behavior, development and morphology are significantly greater and more numerous within the East Atlantic group than within either of the other two. I believe that this is not due solely to the fact that the seals of this group have been more studied, but that it is here that a relatively large population, subdivided into numerous partially isolated groups, gives maximum opportunity for genetic divergence.

If my reconstruction of the history of the three groups is substantially correct, then the West Atlantic group must have separated from the East Atlantic and Baltic groups about 100,000 years ago, while the separation of the two latter groups took place about 9,000 years ago. The separation of the West Atlantic stock would have been contemporary with the splitting of *Phoca v. vitulina* from *P. v. concolor* and, since Doutt (1942), although retaining these two subspecies, could find no valid difference between them, it is not to be expected that very significant morphological differences will be found between the two populations of *Halichoerus*. The Baltic stock has been isolated for a very much shorter time, but this would have been compensated for by the particularly intense selection pressures operating. Doutt's *Phoca v. mellonae* may be instanced as an example of a form isolated for a comparable period in a restricted and strange environment and sufficiently differentiated to merit subspecific rank.

THE ENGLISH VERNACULAR NAME FOR *HALICHOERUS GRYPUS*

At this stage, I would like to make a plea for the abandonment, by some of my friends in Britain, of the vernacular name "Atlantic seal" or even "Atlantic grey seal." It is true that the name "grey seal" may not be particularly appropriate. Many gray seals are not gray in color, but practically all females are so colored and I believe that more gray seals are colored gray than live in the Atlantic Ocean. "Atlantic seal" is therefore no more appropriate and in fact is less so. The name "gray seal" has acquired general usage in North America and (with the exception of Germany) on the European mainland. It was used by all writers in Britain up to about twenty years ago and its use should be continued so that the three major population groups may be known as the West Atlantic gray seal, the East Atlantic gray seal, and the Baltic gray seal.

SUMMARY

The gray seal exists in three distinct population groups, one in the Gulf of St. Lawrence, a second in the British Isles, Faroes, Iceland, Norway and White Sea regions, and a third in the Baltic Sea. World numbers are very small and are probably around 50,000, the East Atlantic being the biggest population group and the West Atlantic the smallest. The movements of seals within the three groups are mainly connected with feeding and are in the nature of seasonal dispersals from the breeding grounds.

The West Atlantic group finally became isolated at the beginning of the last glacial (Wisconsin), while the Baltic group was separated in the post-glacial Ancylus Lake. The three groups are not only isolated geographically but also physiologically, since they have developed widely differing breeding seasons: the West Atlantic and Baltic seals breed on the ice in late winter and early

spring, whereas the East Atlantic seals breed on shore in autumn. Many differences in behavior, development and morphology have been found between the three groups and between the individual colonies of the East Atlantic group.

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THE DENTITION OF THE ALASKAN FUR SEAL

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The dentitional characteristics of mammals have long been considered to be of the greatest phylogenetic significance. Not only have dental patterns been important in differentiating between species and genera but also in determining the relationships of orders. Perhaps even more important in this last regard has been the mode of development and growth of the teeth. The fact that mammalian teeth are heterodont is used as an important criterion in defining the class; and even the origin of this great systematic group has been determined primarily by the fact that mammals, like synapsid reptiles, have a thecodont dentition.

It is evident, then, that drastic differences in dental patterns between one

member and another of the same order of mammals must be explained if the ordinal designations involved are to survive close scrutiny. Certainly the dentition of fissipeds differs drastically from that of the pinnipeds. Any attempt to establish the relationships of these two groups must take these differences into account, and any attempt to include both categories within the limits of a single order must explain the inordinate degree of variability in a normally stable character.

The following description and discussion of the dentition in the fur seal, *Callorhinus ursinus*, attempts to clarify the position of the Pinnipedia as well as the dentitional characteristics which they possess.

MATERIALS AND METHODS

Fur seal specimens for this study consisted of three subadults and two pups, embalmed or preserved in formalin. Forty female and nine male skulls were used which, in both sexes, ranged in age from newborn to 18-year-old adults.

For comparative purposes, skulls of three *Zalophus*, one *Otaria*, and two *Eumetopias* were borrowed from the Chicago Natural History Museum.

The right upper canine teeth of fifteen additional animals of known sex and age were available for sectioning. Sections were cut on a diamond rock saw and ground on lapidary disks.

OBSERVATIONS AND DISCUSSION

The teeth are peg-like or haplodont, and either single- or double-rooted. The canines and incisors are single-rooted. The postcanine teeth are, in most cases, incompletely double-rooted but in some instances may be referred to as double-rooted. However, the double-rooted condition is the result of post-eruptive constriction of the root rather than of pre-eruptive development of two separate roots. This type of double-rooted tooth development appears in the alligator and perhaps in other reptiles but not, to my knowledge, in any other mammal. Figure 1 illustrates the formation of roots in both the fur seal and alligator.

The dental formula of the adult fur seal, according to Lucas (*in* Jordan *et al.*, 1898) is $I\ 3/2, C\ 1/1, P\ 4/4, M\ 2/1 \times 2 = 36$. Allen (1880) had earlier presented the formula as $I\ 3/2, C\ 1/1, M\ 6/5 \times 2 = 36$. He also stated that *Callorhinus* is "... the only North American genus which has the upper molars 6–6."

Allen has presented the following formula for the deciduous teeth: $I\ 3/2, C\ 1/1, M\ 3/3 \times 2$; this was confirmed by Lucas (*op. cit.*). Lucas did not explain his reasons for classifying the postcanine teeth as premolars and molars nor did Allen give any reason for calling them all molars.

Premolars are usually distinguished as those cheek teeth preceded in time by deciduous teeth while permanent teeth, which are never replaced or preceded, are designated as molars. It cannot be assumed that these criteria were used by Lucas since he agrees that there are only three deciduous molariform teeth in each jaw, yet he designates four of these as premolars. Another criterion involves the use of morphological characters to distinguish molars and pre-

molars. This is not applicable to the fur seal, since consistent, significant morphological differences cannot be discerned.

Since no mammal, living or fossil, is known to have more than four deciduous postcanine teeth in each jaw, the primitive mammalian dentition is limited to four upper and four lower premolars on each side. This fact, together with the knowledge that there are no morphological differences in fur seal teeth, probably influenced Lucas' designations.

A significant difference between the adult molariform series and the dentition of the two-year-old seal is the greatly reduced size of the sixth upper molariform tooth of the adult (Fig. 2). This reduction in size is due entirely to the size of the enamel cap or crown. While resorption and reduction of the dentine are possible, resorption of enamel is not. The most reasonable conclusion which can be drawn from this observation is that the sixth upper molariform tooth of the subadult is deciduous and is replaced in the adult seal with a tooth having a smaller enamel crown than that of the two-year-old animal.

Any study of the deciduous teeth in the otariids is complicated by the unusual embryological feature of the resorption of the milk teeth while the embryo is in the uterus of the mother. According to Scheffer (1950), most of the permanent dentition is present at birth. Judging from my observations of a young animal, hardly one month old, the teeth present at birth include all the incisors, the canines, all the lower postcanine teeth, and first, second, third and fifth

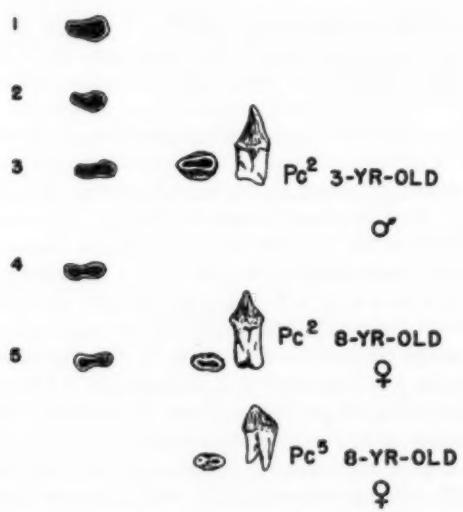

FIG. 1.—Root development. The figures on the left show the stages of root constriction in the alligator. The figures on the right show three stages in the development of the roots of the fur seal tooth. Pc^2, is the second upper postcanine tooth; Pc^5, is the fifth upper postcanine tooth.

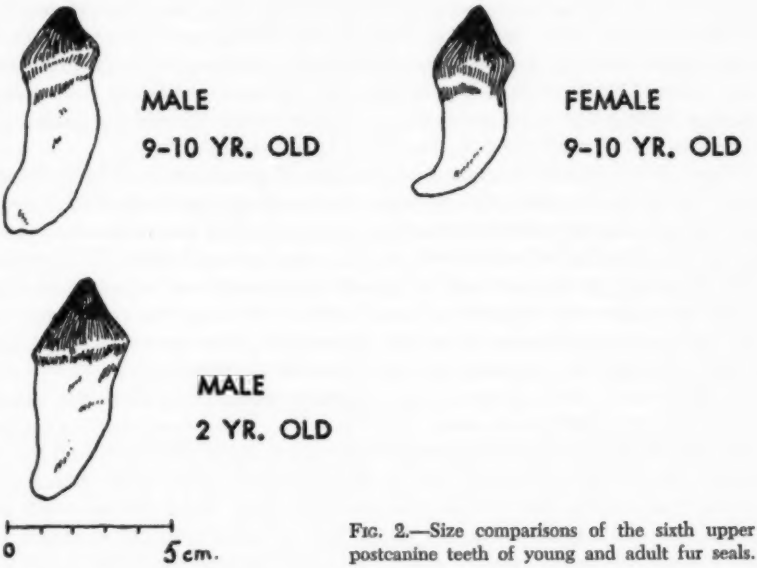

FIG. 2.—Size comparisons of the sixth upper postcanine teeth of young and adult fur seals.

upper postcanines. The fourth upper postcanine tooth probably breaks through the gums either late in the first or early in the second month (see Fig. 3A).

The exposed enamel of all erupted teeth is discolored. According to Lucas (*op. cit.*) this discoloration begins at the tip of the crown and progresses toward the cingulum as the tooth emerges from the gum. By noting the amount of tooth exposure and discoloration on a seal pup we may guess the sequence of eruption of these teeth. By this method the sequence is: Pc^1, Pc^2, Pc^5, Pc^3, Pc^4, and finally Pc^6 for the upper series (Fig. 3A). In the lower series the eruption

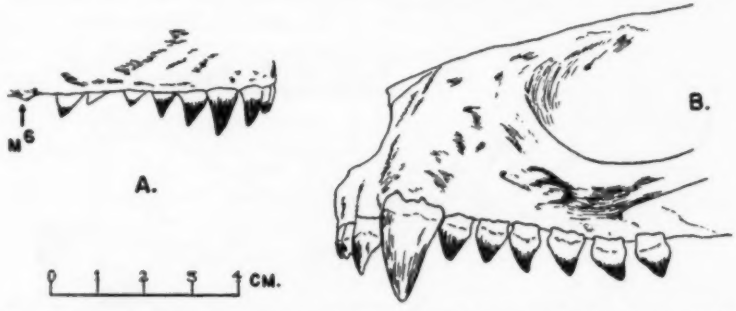

FIG. 3.—Lateral views of the upper teeth of the fur seal at two age levels. *A*, one-month-old female, showing sequence of tooth eruption; M^6, sixth upper postcanine tooth. *B*, two-year-old male fur seal.

progresses in regular sequence from front to rear. The two-year-old seal has a complete set of teeth, including six upper and five lower postcanine teeth. If measured at the cingulum, these postcanine teeth are all approximately the same size. Note (Fig. 3*B*) that there are very few differences either in size or morphology among the members of the postcanine series. A uniform postcanine series was found in all the 2–4-year-old specimens examined.

Mohr (1943) points out that since the jaws of pinnipeds increase in length as the animal grows older, the dentition must undergo some sort of compensatory change. She suggests that enamel is continually laid down, thus increasing the surface of contact of each tooth, until the jaw has reached its full extension. Her measurements of three teeth from each of four seals and of one tooth from a fifth specimen were apparently made without removing the teeth from the jaw. Successive measurements of this type would show increases in the size of the tooth until the cingulum emerged from the alveolus.

In the fur seals studied there are no differences in size of the teeth that cannot be ascribed to individual or sexual variations. The dental compensation for jaw extension consists mainly of the progressive emergence of the teeth from the alveolus. The posterior edge of each of the postcanine teeth of the young pup overlaps the anterior edge of the next posterior tooth. Thus the jaw teeth are at first crowded together (Fig. 4). As the jaws increase in length the teeth not only emerge but, as may also be noted (Fig. 3*B*), become separated from each other by growth of bone between the alveoli so that they are set much farther apart in the adult than in the younger animal. This permits the apices of the crowns to strike the cingula of the opposing series of teeth, thus increasing the total area of occlusion.

The sixth upper postcanine tooth does not occlude with any tooth of the lower jaw at any time during the growth of the animal. This tooth is single-rooted in the adult and its root canal is closed. These three features plus its small size indicate that it is probably becoming progressively more vestigial. The tooth is usually absent in the California sea lion and is either absent or shows signs of degeneracy in the other eared seals.

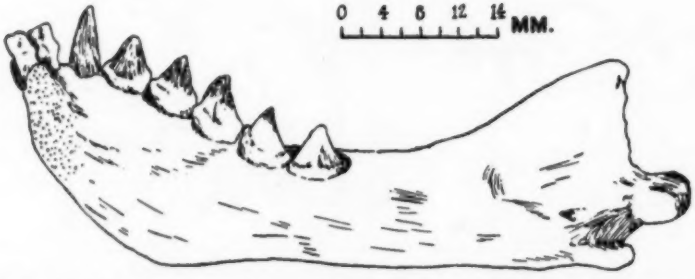

FIG. 4.—Medial view of the right mandible of a one-month-old female fur seal. Parts of the bony sockets have been cut away to reveal the position of the teeth.

The progressive loss of vestigial structures should, I think, be considered as further specialization of the evolving species. In the case of the Alaskan fur seal the sixth upper postcanine tooth is retained as a vestigial structure. The California sea lion has advanced to the point of losing the tooth in most cases but has not yet changed genetically to such a degree as to completely eliminate this character from the entire population.

Allen (1880) believed that the last upper postcanine of the northern sea lion is not the homologue of the fifth or sixth but of a seventh tooth which we cannot find as a regular part of a series elsewhere in the seals. Allen based his conclusion on the length of the diastema between the fourth and last upper postcanines. It seems more reasonable to suppose that the rapid growth and extension of the skull is responsible for the diastema, rather than to explain it by postulating the occurrence of a unique and mysterious seventh postcanine and the suppression of the fifth and sixth teeth of these series.

MICROSTRUCTURE OF TEETH

From birth to the age of at least one month, the entire enamel crown and most of the first cone of dentine are present. The dentine cone extends into the alveolus approximately 2.5 to 3 mm. and this portion of the tooth has no enamel covering. Additional layers of dentine consist of wide pale bands separated by narrow darker lines. The dark areas (Fig. 5) undoubtedly represent the time spent on land during which the animal does not feed and the females are producing young. This is a period of approximately three months. The wider dentine bands, then, are laid down during the nine months spent at sea. These annual bands or cones are arranged as fairly concentric lamellae and such variations as do exist are probably explainable on the basis of metabolic disturbances, such as (1) length of time spent on land, (2) food consumed (both quantity and quality) and (3) effects of parasitism and disease. In this connection it is of interest to note that dental abnormalities which I have observed (Chiasson, 1955) have included no instance of dental caries.

It should be noted that during the two or three months spent on land the energetic metabolism of the male seal is solely dependent upon the utilization of stored fat. This stored fat does not contain the calcium salts used in building enamel or dentine. Other body processes continue, however, so no other mor-

FIG. 5.—Longitudinal sections of the canine teeth of a one-month-old female and a 15-year-old male fur seal. The first-year growth ring of the 15-year-old has been worn away. The dentinal layer on the one-month-old tooth is mainly neonatal. Dentine deposit before birth is very slight.

phological feature reflects this change in metabolism. Even in bone structure, any trace of this period is erased within a short time since bone is continually resorbed and laid down throughout the year.

Growth lines or layers have been reported in the teeth of a variety of vertebrate species. Marsh (1880) referred to the dentine of the fossil bird, *Hesperornis*, as having ". . . distinct concentric lines of growth." Schour and Smith (1934) record the following mode of formation of the incisor of the white rat:

> The enamel, which covers the labial portion of the tooth, and the dentine, which covers the pulp, are laid down in stripes which move forward as they are formed and calcified. These dentine and enamel layers record the rate of growth and register changes in calcium metabolism, just as the rings of the tree indicate seasonal growth, alternate periods of rainfall and drought, and the vicissitudes in the life history of the tree.

According to Vander Hoof (1937) growth lines in the enamel of the fossil sirenian, *Desmostylus* ". . . are caused by a cyclic slowing down of activity of the odontoblasts, during which time the enamel rods at this horizon had a slighter diameter." The error here is most likely typographical or due to an oversight on the part of the author. The substitution of the word "ameloblast" for "odontoblast" renders the statement more accurate. Laws (1952, 1953) indicates that growth lines occur in six different genera of seals: *Mirounga, Cystophora, Hydrurga, Phoca, Lobodon* and *Leptonychotes*, as well as in the sperm whale, *Physeter catodon*. This is the condition in numerous other vertebrates from fishes to humans (Schour and Hoffman, 1939).

Microscopic examination of fur seal teeth, using ordinary light, revealed no such lamellar structure. Growth layers were discernible using polarized light and these became even more distinct when placed between crossed polaroids. Interference colors were at a maximum in the dentine at 90° intervals of analyzer rotation, indicating the existence of a preferential arrangement of the crystalline structure of each layer.

If tooth sections are made so thick as to be opaque to transmitted light, the growth lines may still be seen by reflected light. These thick sections may also be examined by transmitted light after clearing in cedarwood oil for at least 24 hours.

DENTAL PATTERNS

The "Cope-Osborn Theory" (Osborn, 1907) states that carnivores, ungulates and primates each passed through an evolutionary stage in which they had tritubercular upper molars. The theory also states that this stage was preceded by a triconodont condition and that the marginal cusps subsequently migrated outward in the upper, and inward in the lower teeth. Modifications of this theory advanced by others deal mainly with the matter of cusp rotation and the precedence of the tritubercular stage. It is now held that the haplodont stage precedes the tritubercular and triconodont stages, but the triconodont does not necessarily precede the tritubercular stage.

Pinnipeds present an excellent illustration of the tritubercular and triconodont developments. The Phocidae clearly show the triconodont condition, while the

FIG. 6.—Primitive dental patterns of three representative pinnipeds. The alligator tooth, shown for comparison, is typical of the haplodont type.

Otariidae present both haplodont and tritubercular teeth (Fig. 6).

Osborn first presented the hypothesis that pinniped teeth have regressed to these primitive types from the more advanced creodont teeth. Most workers after Osborn have followed his concept. It does not seem probable, however, that the teeth could regress while retaining their primitive cusp characteristics within the regressive framework, nor is this reasoning sound from a genetic standpoint. Genetic characters once established usually do not undergo reverse mutation to a previously discarded condition. Evidence for evolutionary reversibility is shown by factors which affect the Hardy-Weinberg equilibrium, and at this level we are concerned with only a single allele. A structure as complex as a tooth is certainly controlled by several alleles and there is a correspondingly low probability that such reverse mutation would occur.

Kellogg (1922) has reiterated Osborn's concept in part in his statement, ". . . [the teeth] probably exhibited an incipient retrogression of the tritubercular type to the haplodont type." He stated, further, that the haplodont condition, after being re-established, developed secondary cusps.

If we are to accept this hypothesis, we must assume that the pinnipeds developed the complicated creodont tooth and this subsequently regressed to the primitive haplodont condition. This haplodont tooth then redeveloped additional accessory cusps!

There is evidence among the pinnipeds which indicates slight advancement of the dentition in that there is specialization of secondary cusps, but there is nothing to indicate any regression. Regression has previously been assumed, apparently on the basis that otariids (supposedly derived from creodont stock) do not have the specialized dentition characteristic of Creodontia, hence this specialization must have been lost. Wortman observed (Condon, 1906) that while there are certainly some strongly marked creodont features characterizing the skull of *Desmatophoca oregonensis*, it is still far removed from any known member of the creodont group. The same statement might apply to the Pinnipedia in general. Indeed, it is my considered opinion that the concept of a creodont origin should be discarded as being too speculative in view of the lack of supportive evidence.

Ruling out the possibility of retrogressive evolution, we must consider the possibility of tooth degeneracy. Two examples of possible degeneracy may be pointed out for the Otariidae, the first of which concerns the sixth upper postcanine tooth of *Callorhinus* which has already been described (Fig. 2). This tooth has become reduced in size but no apparent structural changes have occurred. The second example concerns the last upper postcanine tooth of *Zalophus*. A skull of *Zalophus* (CNHM 51748) shows the last upper postcanine to be very degenerate (Fig. 7). It consists only of a thin crust of dentine, irregular in shape and without an enamel crown. The author knows of no case of dental degeneracy which has produced a tooth similar to that of the otariids and it seems quite unlikely that the complex creodont tooth could degenerate to a haplodont tooth possessing a definite cingulum and a substantial enamel layer.

I think we may reasonably conclude that the pinniped dentition is the result of progressive evolutionary processes and that the dentition historically was never more complex than in modern representatives of the group.

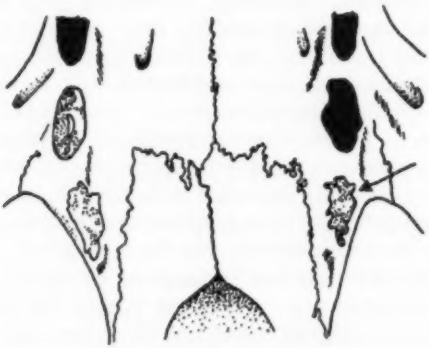

FIG. 7.—Posterior portion of the palate of *Zalophus* (ventral view) showing the degenerate sixth upper postcanine teeth (arrow). *Specimen CNHM 51748.*

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SOME OSTEOLOGICAL CHARACTERS OF KNOWN-AGE RANCH MINKS

By KENNETH R. GREER

Before determining age ratios from samples of wild mink, *Mustela vison*, it is essential to establish some criteria for the females. A report (Lechleitner, 1954) that a supra-sesamoid tubercle was present on the femur of adults of both sexes and absent on juveniles appeared promising. The use of the baculum for distinguishing juvenile and adult males has been established (Petrides, 1950; Elder, 1951).

Grateful acknowledgment is extended to Drs. Don C. Quimby and P. L. Wright for their critical review of this paper. This work is a contribution from

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Known-age ranch mink were collected principally from one Montana rancher in 1953. Supplemental adult age classes were obtained from several Montana ranchers during 1954. Eight mink ranchers supplied a total of 883 known-aged specimens: half-year, 230 males, 265 females; 1½ year, 47, 208; 2½ year, 12, 59; 3½ year, 7, 47; 4½ year, 1, 3; 5½ year, 0, 3; and 6½ year, 1, 0 (one-half year is approximately 8 months).

A dermestid beetle colony was utilized for reducing specimens to skeletal remains. Major bones retained included: skull, atlas, axis, presternum, scapula, humerus, radius, ulna, pelvic girdle, sacrum, femur, fibula, tibia and baculum. The bones of juveniles and adults were compared for clearly perceivable differences. Unbleached specimens were more desirable for analysis. Those exhibiting a relative degree of demarcation were: baculum, femur, skull and pelvic girdle. Prepared bone boards supplied comparative values between age classes. The other bones were considered inadequate for age correlation although some did exhibit minute features of possible distinction.

Baculum.—The bacula of 229 (99.5 per cent) of 230 juvenile males and all (68) adult males conformed with criteria described by Petrides (1950) and Elder (1951).

Femur.—Values of absent, small, medium and large (Plate 1) were used to aid in classification of the supra-sesamoid tubercle of each femur. Differences between age classes (juvenile and adult) were apparent. For convenience, small tubercles were considered absent. Medium and large tubercles were recorded as present. If a femur was lost during preparation its tubercle was considered as having the same prominence as its counterpart.

The critical level of separation is between juveniles (½ yr.) and yearlings (1½ yr.). Approximately 92.5 per cent of the juvenile and yearling known-age specimens were correctly classified on the basis of absence or presence of the tubercle, respectively. The data (Table 1; Fig. 1, Top) indicate juveniles (93.5 per cent) were correctly classified more frequently than yearlings (90.6 per cent). Although the yearling male sample is smaller than samples of other classes, it appears that the males show a greater incidence for a femoral tubercle than females.

Considering the 2½-year and older groups, 93.9 per cent had a tubercle present (92.9 per cent adult females, 100 per cent adult males). Combining all age classes, 819 or 92.8 per cent of 883 are within the respective categories of juveniles and adults by using the absence or presence of the femoral tubercle. Tubercles occurred in adult males (95.6 per cent) more frequently than in adult females (90.9 per cent).

Skull.—Three sutures were evident in the known-age sample (Plate 2): nasal-premaxillary, maxillary, frontal suture; mastoid-exoccipital suture; and jugal-zygomatic process of squamosal suture (Leach, 1946; Romer, 1950; Brown, 1952). The medial (inside) side of the jugal suture in the zygomatic arch

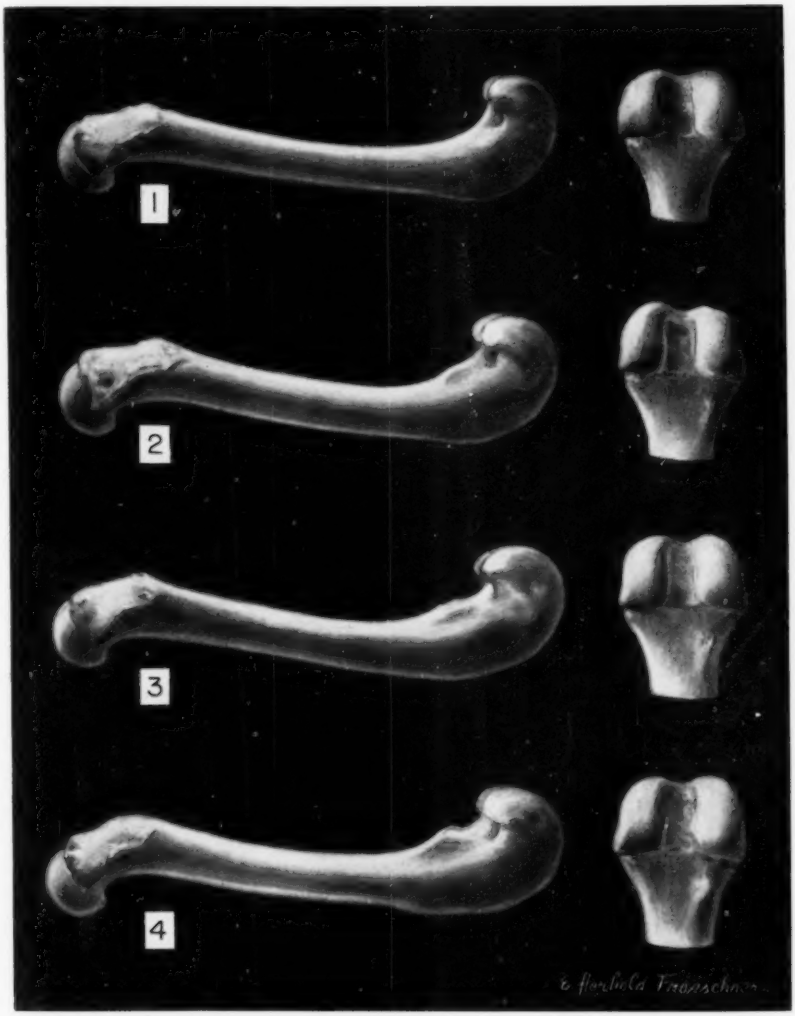


PLATE I

Categories of the supra-sesamoid tubercle on ranch mink femurs. 1—ABSENT: Chalky and spongy aspect at site of tubercle. Entire width of caudal epiphysis appears porous (not homogeneous). Tubercle area conforms to line of shaft. 2—SMALL: Tubercle area has slight concentration from additional deposits. Caudal epiphysis losing porous appearance at extreme sides. Slight elevation of tubercle. 3—MEDIUM: Tubercle area has noticeable deposit. Occasional porous aspect at center of caudal epiphysis. Marked elevation of tubercle. 4—LARGE: Definite, distinct tubercle. Disappearance of porous caudal epiphysis. Definite elevation of tubercle.

was usually ossified and not discernable. Lateral (outside) parts of this suture were recognized at various levels of distinction. With the appearance of ossifi-

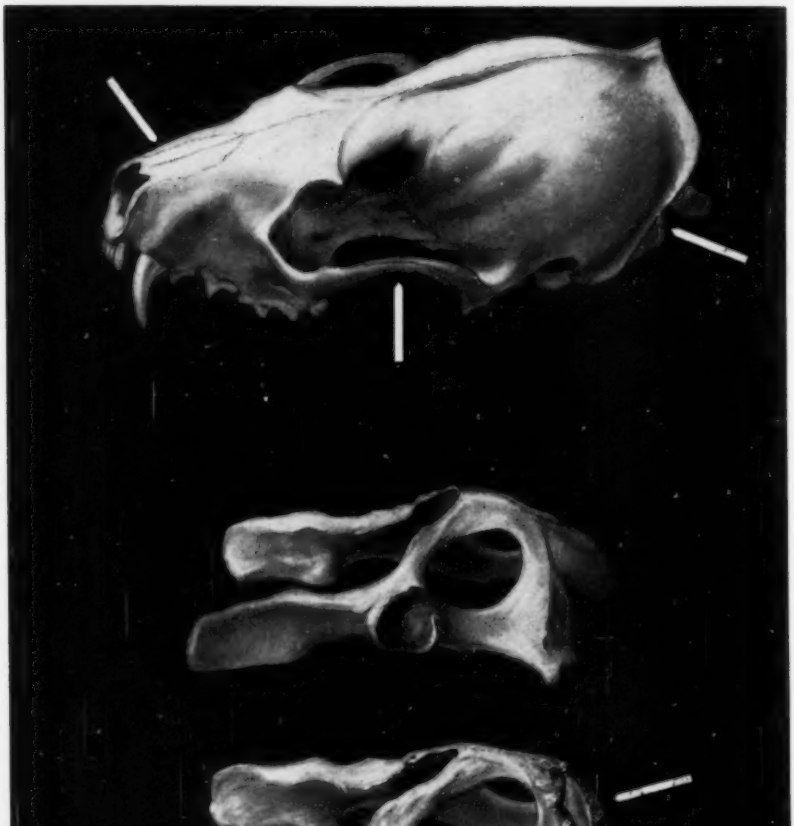


PLATE II

TOP: Sutures discernable in ranch mink skulls (approximately 8 mos. old). Left—nasal-premaxillary, maxillary, frontal suture. Center—jugal-zygomatic process of squamosal suture. Right—mastoid-exoccipital suture. MIDDLE: Pelvic girdle of juvenile male ranch mink with smooth conformation of edge of ischium. BOTTOM: Adult male pelvic girdle with additional deposits on edge of ischium.

cation progressing from the dorsal and ventral edges of the arch, some sutures were recognized as a groove or impression. There were several instances where only a segment of an entire suture could be discerned. It was common for the middle or ventral section of the jugal suture to be the last remnant. When the nasal-premaxillary suture was faint but evident, the color of the nasal and joining bones offered a contrast.

The nasal suture was discernible in 61.3 per cent juvenile males, in 41.1 per cent juvenile females and in one specimen (1½ yr. male) of 388 adults.

The mastoid-exoccipital suture was conspicuous in all age groups and of no value as an aging criterion.

The jugal-squamosal suture appeared to show merit for separation of juveniles (present) and adults (absent); 93.4 per cent are within their respective categories. By using this suture, 95.6 per cent juveniles and 86.3 per cent yearlings are correctly separated. There appears to be very little difference between sexes of the same age groups with this criterion (Table 1; Fig. 1, Middle).

A sagittal crest was considered incomplete if the temporal ridges were apparent in the parietal region of the skull. These ridges prevent the occurrence

TABLE 1.—*Known-age specimens classified within respective category of juvenile and/or adult*

AGE CLASS	TOTAL NO.	STATUS OF FEMUR TUBERCLE, ONLY (Table 3)		STATUS OF JUGAL-SQUAMOSAL SUTURE, ONLY (Table 4)		FEMUR TUBERCLE ABSENT AND JUGAL-SQUAMOSAL SUTURE PRESENT (Table 5)	
		Absent		Present		Number	Per cent
		Number	Per cent	Number	Per cent		
½ yr. male (juvenile)	230	215	93.5	220	95.7	220	95.7
½ yr. female (juvenile)	265	248	93.6	253	95.5	248	93.6
All juveniles	495	463	93.5	473	95.6	468	94.7
		Present		Absent		Tubercle present and suture absent	
1½ yr. male (yearling)	47	44	93.6	40	85.1	43	91.5
1½ yr. female (yearling)	208	187	89.9	180	86.5	199	95.7
All yearlings	255	231	90.6	220	86.3	242	94.9
2½ yr. and older, male	21	21	100.0	21	100.0	21	100.0
2½ yr. and older, female	112	104	92.9	111	99.1	112	100.0
All 2½ yr and older	133	125	93.9	132	99.2	133	100.0
1½ yr. and older, male	68	65	95.6	61	89.7	64	94.1
1½ yr. and older, female	320	291	90.9	291	90.9	311	97.2
All 1½ yr. and older (adults)	388	356	91.8	352	90.7	375	96.6
		Absent (juv)	Present (ad)	Present (juv)	Absent (ad)		
All juveniles and all yearlings	750	694	92.5	693	92.4	710	94.7
All juveniles and all adults	883	819	92.8	825	93.4	843	95.5

of a distinct crest from point of origin, fusion of temporal crests on frontal bones, to occipital crest. It was usual to find an undeveloped crest in the juvenile female (75.5 per cent) but this condition also existed in the adult classes (Table 2). Juvenile males exhibited a more positive development; 11.3 per cent had temporal ridges, the remainder had complete sagittal crests. The absence, presence or prominence of the sagittal crest had no value as an aging criterion. This feature did not show any significant difference in samples between any or all ranches where specimens were obtained.

In all juveniles there was a tendency for the sagittal area to have a gritty or sandpaper-like appearance and a finger rubbed over this surface confirmed this impression. The skulls of adults usually presented a smooth surface to both sight and touch.

Transparent sections from lower canine teeth were also studied. Most secitons had faint and definable annuli but the limited sample did not reveal obvious correlation with known-age specimens as Fisher and Mackenzie (1954) have reported occurring in various pinnipeds.

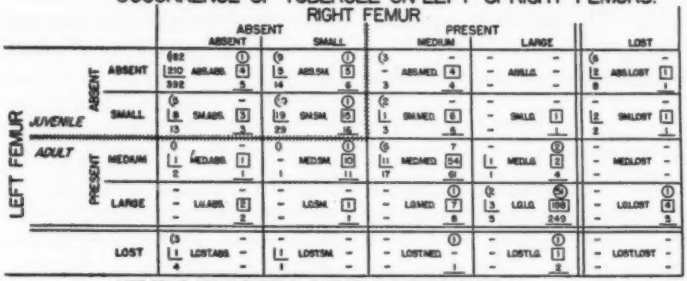
Skull and femur.—By combining both features, absence or presence of tubercle on femur and jugal-squamosal suture, the incidence for proper classification of 883 juveniles and adults was 843 or 95.5 per cent. The degree of accuracy of classification was about equal for juvenile (94.7 per cent) and yearling (94.9 per cent) classes. More juvenile males were correctly classified than juvenile females, whereas the reverse was true between sexes in the adult class. These criteria allowed 97.2 per cent of 320 adult females to be properly designated while the independent use of femur and suture show their respective frequency to be the same, 90.9 per cent.

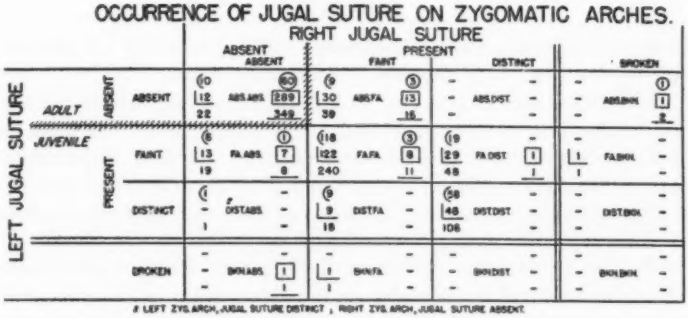
The dividing line designated in Fig. 1, Bottom, offers a higher incidence for correct classification, of the total sample, than any other delineation. The four central combinations have observations insignificant in affecting totals and permitted an easier interpretation for classification.

If: *A*—Tubercle absent on both femurs *and*
Suture absent on both zygomatic arches ..... adult
B—Tubercle present on either femur *and*
Suture absent on either zygomatic arch ..... adult
C—All other combinations ..... juvenile

Pelvic girdle.—The innominate bone did not reveal evident sutures between the ilium, ischium and pubis. Differences that did exist on the internal and external pubic symphysis were: distinct suture between innominate bones; external pubic symphysis ossified; bone deposits along pubic symphysis, corner of pubis and posterior edge of the ischium; and bone nodule and/or ossification of internal pubic symphysis. No correlation could be found for the erratic variations that existed in the ossification of pubic symphysis and reproductive history of specimens.

The posterior surface of the ischium offered a means of separating juvenile from adult males. The juvenile has a smooth edge whereas the adult has a





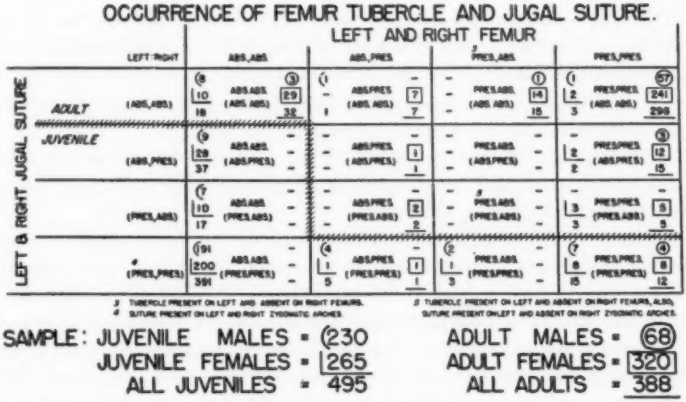


FIG. 1.—Top: tubercle magnitude of each femur; middle: appearance of each jugal suture; bottom: status of four features per individual.

roughened surface due to additional deposits on the posterior edge of the ischium (Plate 2). The growth is apparent in the yearlings and appears more pronounced with increased age. This feature was recognized on all adult males and was absent on all juvenile males.

TABLE 2.—*Incidence of incomplete sagittal crests*

AGE GROUP	MALE			FEMALE		
	Sample	Incomplete	%	Sample	Incomplete	%
½ year	230	26	11.3	265	200	75.5
1½ year	47	1	2.1	208	76	36.5
2½ years and older	21	0	—	112	10	8.9

DISCUSSION

The features investigated on known-age ranch minks did not provide age-class distinction other than between juveniles and adults.

Petrides (1950) and Elder (1951) have established the use of the baculum for determining juvenile and adult minks. Its validity is further substantiated in this study. Separation of juveniles and adults by baculum conformation only is an accurate and convenient criterion which does not necessitate further skeletal preparation and examination. Retention of male skeletons was necessary for a control in confirming aging criteria before application to the female.

Juvenile bacula exhibited a mode of development into the adult configuration. Variations existed in formation of the ridge, point of attachment for the corpus cavernosum penis, by appearance of a bony protuberance. Seventy-four were bare (B) of any bone deposit, 69 showed a dorsal (D) development, 8 on right (R) side and none on left (L) side. Twelve had deposits on D R L, 65 with D R and 2 on R L. More than two-thirds of the juvenile sample had protuberances on the dorsal and right side. This seems to indicate that the dorsal keel appears first, followed by a nodule on the right side, and continued growth elongates deposits on all surfaces to form the adult ridge.

Development of the posterior edge of the ischium of male pelvic girdles is a feature which separated juveniles from adults as readily as the baculum. This criterion was not evident on the females.

Lechleitner (1954) suggests the absence of the supra-sesamoid tubercle on one femur to indicate a juvenile but its presence, an adult. This study utilized both femurs and 87.6 per cent of the total sample exhibited the tubercle prominence to have the same interpretation (abs-abs, sm-sm, med-med, lg-lg). When single femurs were accorded a value similar to the missing mate, 90.5 per cent of all specimens had paired values. By consolidation into an absent (abs. and sm.) and present (med. and lg.) grouping, 9.5 per cent displayed opposite values for femur prominence, of which 50 per cent were adult females (Table 3).

It would appear that the adult male class, 95.6 per cent, had a higher incidence of the femoral tubercle than the adult female, 90.9 per cent (Table 1). How-

ever, the difference is not statistically significant by the chi-square test. On the other hand, when adult sexes were segregated for the presence of a femur tubercle on the left side, the males exhibited a significantly higher percentage. Chi-square was significant at the 10 per cent level but not at the 5 per cent level. The right side did not show a statistical significance.

Lechleitner (1954) indicated that skull measurements were not reliable as aging criteria and therefore this expression was not investigated. He also reported no instances of open sutures on his sample of ranch-mink skulls. This study revealed three sutures that were apparent in ranch skulls, of which two are valuable for age determination. Since the nasal sutures were observed in approximately 50 per cent of the juvenile specimens and only one instance of all adults, it seems that the presence of this suture would indicate a juvenile animal. Wright and Rausch (1955) noted that the malar-temporal suture was open in juvenile wolverines and closed in adults.

With the female mink still requiring accurate methods for aging, it appears that the jugal-squamosal suture of the zygomatic arch may offer a valid criterion. In only 12 of 265 juvenile females was the jugal-squamosal suture absent, whereas only 21 of 320 adult females showed signs of this suture. In the juvenile female class, approximately 30 per cent lacked paired suture values, *i.e.*, had sutures open on one side but not on the other (Table 4). Approximately 50 per cent of the specimens having opposite femur values (absent, left; present, right) were in the adult female class. From the above, it is deemed most important that consideration be given to both sides of these criteria for an accurate age classification.

In the juvenile female class, presence of the zygomatic suture was of greater occurrence than absence of the femoral tubercle. The yearling female class showed that a combination of both criteria increased their individual incidence. The 2½-year and older female class had a higher value for the absence of a zygomatic suture. In the entire class of adult females, the combination of both fea-

TABLE 3.—*Paired and unpaired values for the femur tubercle*

AGE, SEX, NO.	PAIRED						UNPAIRED			
	* Absent		Present		Total	%	†			
	Ab Ab	Sm Sm	Med Med	Lg Lg			Pr Ab	Ab Pr	Total	%
Juvenile male (230)	191	10	6	2	209	90.9	7	14	21	9.1
Juvenile female (265)	213	22	11	3	249	93.9	9	7	16	6.0
Adult male (68)	1	1	8	53	63	92.6	2	3	5	7.4
Adult female (320)	5	16	54	203	278	86.9	24	18	42	13.2
Total (883)					799	90.5			84	9.5

* Tubercle absent on left and right femurs.
† Tubercle present on left femur and absent on right femur.

tures is necessary to obtain a greater probability of correct classification of adult females. By combining the two paired criteria, femur tubercle present and jugal-squamosal suture absent, 97.2 per cent of all adult females were correctly classified whereas the independent use of femur and suture was 90.9 per cent respectively.

The data (Table 5) indicate that the absence of the jugal-squamosal suture in adult females is more valid than the presence of a femoral tubercle (left), 95.0 and 87.5 per cent, respectively. Testing with the standard normal curve (Ostle, 1954), these criteria are significant at the 1 per cent level for the left side, whereas the right side is significant at the 5 per cent level.

Among juveniles, the suture was present slightly more often on the right side than on the left; among adults, it was absent more frequently on the left than on the right side. Testing each age and sex class, the juvenile female group was the only one to show a significant difference for the presence of a suture between the left or right side. At the five per cent level, the right side was more certain to have the suture than the left side.

Age classes and groupings (Table 1) were analyzed for variations between absence or presence of a tubercle on femur and jugal-squamosal suture, respectively. Testing with the standard normal curve, the 2½-year and older grouping is the only one to show significance and this was influenced by the female class only. A statistical hypothesis that the presence of a tubercle on the femur is independent of the absence of a jugal-squamosal suture is rejected at the 5 per cent level. With this same test, no other groupings showed an association between the two features.

At times, additional criteria affording aid in classification of juvenile specimens were: sandy or porous appearance along sagittal crest area, evident nasal sutures, and discernible epiphyses. An adult frequently appeared with an increased height, thickness, and arc of the jugal-squamosal area of the zygomatic arch; smooth and glossy sagittal crest area and absence of nasal sutures.

Variations and extremes are inevitable among samples of wild mink populations which have developed, competed and existed on a self-sustaining basis as compared to ranch-raised animals. It is recommended that aging criteria

TABLE 4.—*Paired and unpaired values for the jugal-squamosal suture*

AGE, SEX, NO.	PAIRED						UNPAIRED				
	Absent		* Present			Total	%	†			Total	%
	Ab	Ab	Fa	Fa	Dist Dist			Pr	Ab	Ab Pr		
Juvenile male (230)	10		118	58		186	80.9	16	28	44		19.1
Juvenile female (265)	12		124	48		184	69.4	22	59	81		30.6
Adult male (68)	61		3	—		64	94.1	1	3	4		5.9
Adult female (320)	291		8	—		299	93.4	7	14	21		6.6
Total (883)						733	83.0			150		16.9

* Suture present on left and right zygomatic arch.
† Suture present on left and absent on right zygomatic arch.

TABLE 5.—*Status of femur tubercle and zygomatic suture on ranch minks*

AGE, SEX, NO.	FEMUR TUBERCLE Absent		ZYGOMATIC SUTURE Present	
	Left	Right	Left	Right
½ yr. male (230)	220 (95.7)	217 (94.3)	211 (91.7)	213 (92.5)
½ yr. female (265)	249 (93.9)	249 (93.9)	223 (84.2)	240 (90.6)
	Present		Absent	
1½ yr. male (47)	44 (93.6)	44 (93.6)	43 (91.4)	41 (87.2)
1½ yr. female (208)	180 (86.5)	178 (85.6)	192 (92.3)	187 (89.9)
All adult males (68)	65 (95.5)	64 (94.1)	64 (94.1)	62 (91.2)
All adult females (320)	280 (87.5)	279 (87.1)	304 (95.0)	298 (93.1)

determined from this collection of known-age ranch mink be applied to wild samples to determine the validity and adequacy of these features for management purposes.

It is suggested that efforts be continued to obtain a means for determining year-age classes. If seasonal annuli from tooth sections could be interpreted and established for mink, the method would be most desirable. If substantiated, it would provide an expeditious and economic technique for preparation and analysis of large samples. Analysis of the variations in ossification of the pubic symphysis and deposits on the posterior edge of the ischium of male pelvic girdles may provide an interpretation for refined age classification.

SUMMARY

A collection of 883 known-age mink specimens (298 males, 585 females) was obtained from Montana mink ranchers during the 1953 and 1954 pelting seasons. Criteria determined from the males were verified by baculum conformation before application to the females. By baculum conformation only, 229 of the juvenile male sample (230) and all adult specimens (68) were correctly classified. Bones useful for distinguishing juveniles and adults were the baculum, femur, skull and pelvic girdle.

Two categories of the supra-sesamoid tubercle, absent (absent and small) and present (medium and large), were apparent on each femur. This criterion separated 92.8 per cent of the total specimens within their respective category of juvenile and adult. Three sutures evident in the known-age skull were: nasal-premaxillary, maxillary, frontal suture; mastoid-exoccipital suture; and jugal-zygomatic process of squamosal suture. The presence (juveniles) or absence (adults) of a jugal suture separated 93.4 per cent of all specimens within their respective categories. The sagittal crest had no value as an aging criterion. Variations existed in the internal and external pubic symphysis. The ischium edge of the pelvic girdle offered a distinction between the juvenile and adult male.

By combining both features, absence or presence of tubercle on femur and jugal-squamosal suture, the incidence for correct identification of 883 juveniles and adults was 843 or 95.5 per cent. These criteria (femur tubercle, present; jugal-squamosal suture, absent) permitted 97.2 per cent of 320 adult females to be properly designated while the independent use of femur and suture show their respective frequency to be the same, 90.9 per cent. A three-choice category is derived from the sixteen probable combinations of the two paired features. Data indicate the importance for analyzing paired values of criterion for accurate age classification.

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NATURAL HISTORY OF THE BANNERTAIL KANGAROO RAT IN NEW MEXICO

BY R. HOLDENRIED

The Santa Fe Field Station was established in July 1951 by the Communicable Disease Center to study the biological relationships of mammals and their ectoparasites to the spread and perpetuation of sylvatic plague. A general description to give an integrated view of the area, methods of study, species of mammals investigated, and most frequently collected species of fleas has been prepared by Holdenried and Morlan (1956). The present report gives detailed observations on the natural history of a single rodent species. The information is submitted in the hope that some of the facts may contribute to eventual understanding of the complex factors involved in dissemination of rodent-borne diseases.

Characters distinguishing the bannertail kangaroo rat, *Dipodomys spectabilis baileyi* Goldman, from other rodents include large muscular hind legs and large hind feet used for bipedal locomotion, small weak front legs and feet used mainly for manipulating food, a long tail with a white tuft 50 to 70 mm. long, a broad head with short rounded ears on a short neck, and hair-lined cheek pouches.

This rat, well adapted to semiarid grassland climate, prospers on a diet of dry seeds (Schmidt-Nielsens, 1950) which can only irregularly and at long intervals be supplemented with food containing free water. A satisfactory water balance is maintained through excretion of minimal amounts of water in urine and feces and engaging in above-ground activities at night while the temperatures are lowest and air humidities are highest. In the hottest, driest period of the day the rat remains in its cooler, more humid burrow where water evaporation through breathing is reduced.

STUDY AREA

The bannertail kangaroo rats at Santa Fe occupy the flatter open grassland portions of the arid Upper Sonoran Life Zone up to about 7,000 feet above sea level. Avoided are the piñon pine-juniper forest though ridges and ravines with scattered juniper or piñon pine growth may be inhabited. Animals were obtained for study from several locations near Santa Fe. However, the most intensive observations were made on a portion of the Santa Fe Municipal Airport, 7 miles southwest of the town. The airport, at an elevation of from 6,200 to 6,300 feet, consisted of a somewhat leveled mesa containing the airplane runways and taxiways. The mesa drops steeply about 40 feet on the southeast and north-

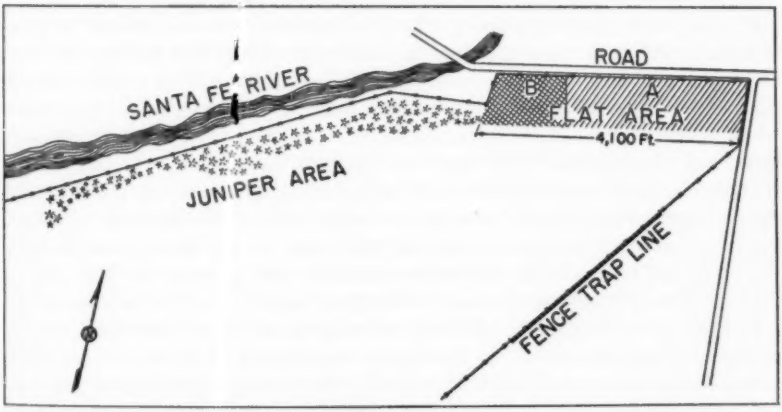

FIG. 1.—Diagram of trapping area on a portion of the Santa Fe Municipal Airport, Santa Fe County, New Mexico. Flat Area A: area trapped regularly until end of September, 1953. Flat Area B: most trapping terminated by October 1, 1952. Fence Line: trapping at night terminated March 31, 1952; day trapping continued until November 13, 1952. Juniper Area: area inhabited by few *Dipodomys spectabilis*.

west sides. Cattle have been excluded by a fence erected in 1943, but the surrounding area has been closely grazed by domestic stock. Per unit area, the amount of ground covered by herbaceous plants inside the fence exceeded that on the outside. The most obvious difference between the two areas was the increased vertical height of the ungrazed plants. The bannertail kangaroo rat inhabited both areas without noticeable preference.

The intensive study of *D. spectabilis* at the airport was restricted primarily to one slightly rolling area shown in Fig. 1 as Flat Area A and B. This area of approximately 66 acres (4,100 × 700 feet) supported a herbaceous plant growth. Two other trapped areas, one (Juniper Area in Fig. 1) extending for 7,300 feet from a corner of trap line No. 2, and the other a 2,630-foot straight line along a fence (Fence Trap Line in Fig. 1) supplied interesting information on movements. The fence line, 1,250 feet from the edge of the first area at the closest end, extended diagonally to 2,950 feet distant at the farthest end.

METHODS

The traps used (described by Holdenried, 1954) were of three types, as follows: (1) Young's rat traps constructed of wire mesh with solid metal doors on each end that raised when set; (2) a trap designed by station personnel, 4 × 4 × 15 inches, constructed of wire mesh with a solid metal door at one end; (3) a solid metal Sherman-type trap 3 × 3 × 10 inches in size. Of the three types, the second trap proved the most efficient and satisfactory for capturing *D. spectabilis* and was used most extensively.

In the intensively studied area, traps were set at burrows that appeared to be used by *D. spectabilis* and other rodents. Each of these sets was marked by a numbered metal plate attached to a heavy wire inserted in the ground. A piece of light reflective material attached to each marker simplified finding the traps at night. Sufficient light was reflected from a flashlight to be readily seen at distances of over 100 yards. Trap bait consisted of a mixture of oat groats and whole wheat. When captive animals were left in the field overnight, an additional ball of moistened rolled oats was placed in each of the wire mesh traps. If captive animals overturned the bait cups, allowing the grain to pour through the wire mesh floor where it was out of reach, the ball of rolled oats remained available for food. Except for the first few weeks of the study, each location was retrapped once a week. Inclement weather or interruptions by other studies prevented completing the once-a-week trapping schedules on but few occasions.

In 1951, prior to October, one week of trapping had been completed in July and another in September. The last regular trapping for *D. spectabilis* was completed in the last week of September, 1953, but one night of restricted trapping was accomplished early in November. Thus, a 2-year period of nearly regular weekly observations of trapped animals, with irregular observations in three additional months, was completed. Recapturing of *D. spectabilis* was complicated by fluctuating numbers of other rodent species which shared the study area. For example, early in 1952 the number of animals (particularly *Dipodomys*

ordii) captured in one night of trapping increased beyond that which could be satisfactorily handled in the laboratory. To reduce the catch to a manageable size, night-trapping along the Fence Trap Line was discontinued at the end of March, 1952. For the same reason trapping after October, 1952, was discontinued on Flat Area B, reducing the size of the area from 66 to 43 acres. Few *D. spectabilis* lived on the third (juniper) area and decreased trapping there did not influence the numbers of this species captured.

FINDINGS

Mounds.—D. spectabilis constructs large mounds of mixed earth and plant debris thrown out of its burrows. These mounds may measure over 10 feet in diameter and may be raised 2 to 3 feet above the surrounding ground surface. As many as a dozen burrows with oval openings 2 to 3 inches wide and about 4 inches high penetrate the mound from several directions, though frequently only 2 or 3 appeared to be in use at one time. Openings may be plugged in the daytime, perhaps to keep out predaceous snakes as suggested by Vorhies and Taylor (1922), and according to the Schmidt-Nielsens (1950) to conserve water. Although carnivorous snakes and low humidities were present, plugged burrows were infrequently observed at Santa Fe. The "honeycomb" mounds uninhabited by *D. spectabilis* soon collapse, leaving a raised cone-shaped ridge of earth around a central depression. Even portions of currently used mounds collapsed and were gradually re-excavated by the inhabitant.

These mounds, as mentioned by Bailey (1931), were constructed in the open, only occasionally appearing at the base of woody plants such as junipers. In southern Arizona, 90 per cent of the mounds constructed by *spectabilis* were found at the base or edge of trees and brush (Vorhies and Taylor, 1922). Perhaps *baileyi* was sufficiently adapted to the open grassland habitat to be independent of the protection offered by the roots and canopy of trees and brush, while *spectabilis* occupied a more densely brush-covered area and derived advantageous protection from this brush.

On the Flat Area A and B there were 181 mounds, varying from those kept in repair by the present inhabitants to old, scarcely discernible cones. In the period of the study no new mounds were started in this area. Old mounds are frequently reinhabited by *D. spectabilis* or used by a variety of other vertebrate and invertebrate species. Rodents using old and even currently inhabited *spectabilis* mounds were *D. ordii, Perognathus flavus, Onychomys leucogaster* and *Citellus spilosoma. Sylvilagus audubonii* used the entrances for shelter and at times was observed to disappear into the burrows. The burrows, often the only protection from high daytime ground-surface temperatures and from predators, were available to reptiles. Gopher snakes (*Pituophis cantenifer affinis*), rattlesnakes (*Crotalus viridis*), and several species of lizards used these shelters.

No positive information on the number of kangaroo rats inhabiting a single burrow system was obtained in the current study, but Vorhies and Taylor (1922) gassed and then excavated 25 or more *spectabilis* mounds without finding more

than one adult animal in a den. The subspecies *baileyi* probably lived separately at the airport.

The kangaroo rat, through the construction of loose earth mounds, provided suitable conditions for Russian thistle (*Salsola kali* L.) and this thistle frequently flourished. It was absent or widely scattered over the surrounding area. Wildlife of many species utilized first the young growing stems and leaves and later the seeds of the thistle. In the long winter period, *spectabilis* fed extensively on the seeds.

The mounds, attractive to rodents of several species, offered a point for possible exchange of disease both directly between individuals and indirectly through contamination of the environment or through exchange of arthropod vectors. Morlan (1955) found that fleas normally collected from *D. spectabilis* were also present on *P. flavus, D. ordii, O. leucogaster* and *C. spilosoma* and, conversely, fleas most closely associated with other rodents were also taken from *D. spectabilis.*

Population.—The kangaroo rat population of the area studied was followed fairly successfully by the method of recapturing marked individuals. The adaptability of these rats to this type of study is indicated by the recapture records which follow: 57 per cent were captured from 1 to 10 times; 20 per cent from 11 to 20 times; 14 per cent from 21 to 30 times and 9 per cent from 31 to 40 times. A total of 172 *spectabilis* were captured on the airport study area, of which 107 were taken on Flat Area A. Only these 107 animals will be considered in the discussion of population because other areas were less intensively trapped for kangaroo rats or trapping was not continued through all of the study period. Area A was bounded on two sides by roads which did not act as barriers to rodents but did form strips free of mounds. Aside from the roads, there was no separation of the trapping plots from the similar-appearing surrounding land. Some of the marked animals undoubtedly passed freely and may have lived at least part of the time outside of the trapped area. Table 1 shows the number of *spectabilis* captured each month on Flat Area A. The number captured was a fair indication of the actual number present in each month though some roving individuals or short-term residents undoubtedly evaded the traps. The average of from 4 to 9 *spectabilis* per 10 acres given in Table 1 is not intended to imply that these animals were evenly distributed over the area. For example, a swale about 100 feet wide running the length of the area, though never flooded in the period studied, contained mounds only along its margins and there was uneven distribution over the rest of the area.

Table 1 indicates that the large number (38) of rats present in October, 1951, declined rapidly to a low (20) in January, 1952. The population, from March through June, gradually increased as young of the year became active aboveground. However, the number present on the area remained nearly constant from May through September. In 1953, the population increased only slightly with the appearance of young. Not only few young were trapped but the proportion of the population disappearing increased as indicated by the smallest

number of rats in the entire study period being captured in September, 1953. Only a small breeding population would survive into 1954. Even with the most satisfactory conditions in the coming year the population would not regain the numbers found in 1951.

In spite of considerable effort to prevent disturbance and injury in the trapping procedure, 10 animals (6 males, 4 females) died in traps. Deaths due to excessive exposure of captive animals to heat and cold and to starvation after

TABLE 1.—*Number of individual Dipodomys spectabilis captured on Flat Area A*

MONTH	FIRST CAPTURE			RECAPTURED			TOTAL CAPTURED	NO. PER ACRE
	Male	Female	All	Male	Female	All		
1951:								
July*	4	2	6	0	0	0	6	
Aug.	–	–	–	–	–	–	–	
Sept.*	4	14	18	4	1	5	23	
Oct.	10	7	17	7	14	21	38	0.9
Nov.	1	0	1	11	15	26	27	0.6
Dec.	2	0	2	10	10	20	22	0.5
Total	21	23	44					
1952:								
Jan.	1	1	2	9	9	18	20	0.5
Feb.	0	1	1	10	9	19	20	0.5
March	1	2	3	10	0	19	22	0.5
April	4	4	8	10	10	20	28	0.7
May	4	4	8	11	11	22	30	0.7
June	2	5	7	13	10	23	30	0.7
July	3	4	7	13	10	23	30	0.7
Aug.	0	3	3	16	10	26	29	0.7
Sept.	1	1	2	15	12	27	29	0.7
Oct.	1	0	1	13	11	24	25	0.6
Nov.	0	1	1	13	10	23	24	0.6
Dec.	0	0	0	10	10	20	20	0.5
Total	17	26	43					
1953:								
Jan.	1	0	1	10	9	19	20	0.5
Feb.	0	0	0	10	9	19	19	0.4
March	1	0	1	8	9	17	18	0.4
April	4	0	4	7	8	15	19	0.4
May	0	2	2	11	8	19	21	0.5
June	5	3	8	11	6	17	25	0.6
July	1	1	2	10	6	16	18	0.4
Aug.	0	0	0	10	7	17	17	0.4
Sept.	1	0	1	9	6	15	16	0.4
Oct.	–	–	–	–	–	–	–	
Nov.*	1	0	1	5	4	9	10	
Total	14	6	20					

* Months of incomplete trapping.

entrance into unset and unbaited traps occurred by years as follows: 1951, 4; 1952, 3; 1953, 3. No females were killed after July, 1952. Deaths attributable to trapping were scattered over the 27-month study period. While the influence on the total population was undetermined, it was thought to be slight. The population decline at the airport in the fall of 1953 apparently extended to the surrounding region where a reduction in the number of mounds used by *spectabilis* was also evident. The peak number of kangaroo rats was taken in October, 1951, but apparently many of these animals were not established and were moving about more or less homeless as indicated by 18 (47 per cent) of the 38 taken in this month not being captured after December. In 1952, with a similar population (25) in October, only six (24 per cent) were not taken after December. The same number were trapped in January of each year (10 males, 10 females in 1952; 11 males, 9 females in 1953). The 1953 population decline was associated with a decrease in the number of young trapped.

Young kangaroo rats grew rapidly; some young born early in February reached adult weights in May. Most young were captured and marked early enough to allow classification as young or adult, by weight. The period in which young became independently active and were first trapped extended from February through September. In the February–September period, in 1952, 40 new animals were captured. In the same period in 1953, only 18 were taken. Although data for a comparable period in 1951 were not available, the capture in October, 1951, of 38 kangaroo rats, the largest number taken in any single month of the study, indicated that the number of young produced earlier in the year must have been large. Factors that might adversely influence the production and survival of young were not determined. Precipitation at Santa Fe is always limited and because of its influence on plant growth might be of special importance. Temperature-rainfall graphs (Fig. 2) for the airport show the amount of precipitation in each month. Rainfall was below normal in each year but was particularly deficient in April and May, 1953. As a result, many species of plants did not grow or grew only briefly in the late summer. In 1952, many species of plants grew and fruited in April, and responded again to the July and August rains. In spite of the limited 1953 plant growth no evidence of starvation in kangaroo rats was obtained. If reduced plant growth was a factor in the population decline, the influence must have been indirect. The growth of young in 1952 and 1953 was similar, and old animals maintained about the same weights.

Sex ratio.—On Flat Area A the proportion (Table 2) of male and female kangaroo rats trapped was fairly well balanced though the number of males exceeded the females in 15 of the 26 months, equalled the females in 8 months, and was exceeded by females in 3 months. Males composed the largest percentage of the population in the last months of the study when the number of animals was low and the percentage was greatly influenced by the appearance or disappearance of a single animal. In 26 months of trapping, 51 (48.1 per cent) of the total (107) animals taken were males; of the total of 172 kangaroo rats taken on all of the areas trapped at the airport, 87 (50.6 per cent) were males.

Survival.—The survival of kangaroo rats on Flat Area A, as revealed by recapturing of marked animals, is shown by month of original capture in Table 3. Forty-three adult kangaroo rats were first captured in the September–December period of 1951. Five (12 per cent) of these 43 were recaptured in September, 1952. In a similar period (September–December) in 1952, 32 adults were captured of which seven (22 per cent) survived to September, 1953. Comparison of the survival rate for the two years is complicated by the death, due to trapping, of six kangaroo rats originally captured in 1951 and four captured over a similar period in 1952–1953. Had all the animals dying in traps lived, the survival rate for the September–December captured animals in 1951 and 1952 would have been 27 and 34 per cent, respectively. Excluding from consideration those that died in traps, 14 and 25 per cent survived. From January–June, 1952, 29 new animals (mostly young) were captured. Fifty-two per cent (15 animals) survived to September, 1952. Of the 16 new (mostly young) rats captured from January–June, 1953, seven (44 per cent) survived to September, 1953. Rats that died in traps numbered one in 1952 and none in 1953. Even with the smaller population present in 1953 fewer young rats remained on the area than remained in the preceding year. Only one kangaroo rat, a male, was captured over a period of more than two years. It was still present at the close of the study, 769 days after its first capture. The maximum number of days between first and last capture for females was 623. Of the 107 kangaroo rats marked on Flat Area A, 11 were recaptured over a period of at least 360 days. Only 55 (51 per cent) of the animals captured on this area had records extending over 90 days. Disappearance of kangaroo rats from the trapping area was

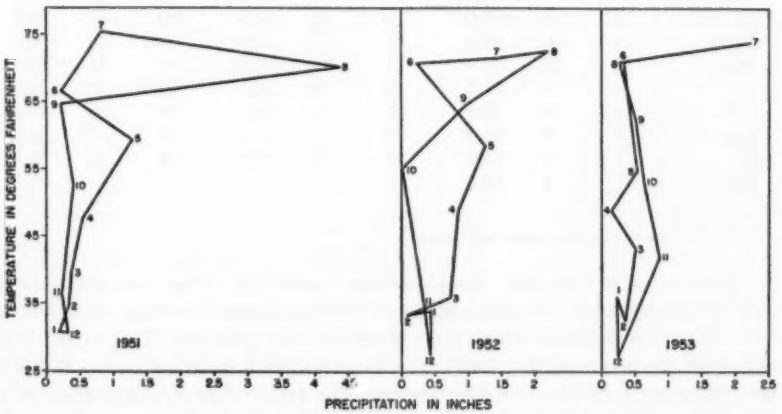

FIG. 2.—Temperature–rainfall graphs representing the monthly mean temperature–precipitation relationships in years 1951, 1952 and 1953 at the Santa Fe Municipal Airport. Smallest numbers of *Dipodomys spectabilis* occurred in 1953, a year with little, poorly-spaced rainfall.

TABLE 2.—*Sex ratio of Dipodomys spectabilis on Flat Area A*

DATE	NEW CAPTURES			TOTAL CAPTURES			CUMULATIVE TOTALS		
	Males	Females		Males	Females		Males	Females	
	No.	No.	Per cent	No.	No.	Per cent	No.	No.	Per cent
1951:									
July*	4	2	33.3	4	2	33.3	4	2	33.3
Sept.*	4	14	77.8	8	15	65.2	8	16	66.7
Oct.	10	7	41.2	17	21	55.3	18	23	56.1
Nov.	1	0	00.0	12	15	55.5	19	23	54.8
Dec.	2	0	00.0	12	10	45.4	21	23	52.3
1952:									
Jan.	1	1	50.0	10	10	50.0	22	24	52.2
Feb.	0	1	100.0	10	10	50.0	22	25	53.2
March	1	2	66.6	11	11	50.0	23	27	54.0
April	4	4	50.0	14	14	50.0	27	31	53.4
May	4	4	50.0	15	15	50.0	31	35	53.0
June	2	5	71.4	15	15	50.0	33	40	54.8
July	3	4	57.1	16	14	46.7	36	44	54.0
Aug.	0	3	100.0	16	13	44.8	36	47	56.6
Sept.	1	1	50.0	16	13	44.8	37	48	56.5
Oct.	1	0	00.0	14	11	44.0	38	48	55.8
Nov.	0	1	100.0	13	11	45.8	38	49	56.3
Dec.	0	0	00.0	10	10	50.0	38	49	56.3
1953:									
Jan.	1	0	00.0	11	9	45.0	39	49	55.7
Feb.	0	0	00.0	10	9	47.4	39	49	55.7
March	1	0	00.0	9	9	50.0	40	49	55.1
April	4	0	00.0	11	8	42.1	44	49	52.7
May	0	2	100.0	11	10	47.6	44	51	53.7
June	5	3	37.5	16	9	36.0	49	54	52.4
July	1	1	50.0	11	7	38.9	50	55	52.4
Aug.	0	0	00.0	10	7	41.2	50	55	52.4
Sept.	1	0	00.0	10	6	37.5	51	55	51.9
Nov.*	1	0	00.0	–	–	–	–	–	–

* Months in which area was incompletely trapped.

not always due to mortality. Some animals moved out of the area and others, already adults at first capture, moved to it. Data from this study do not indicate actual survival rates which must be somewhat higher than calculated. The data indicate, however, that kangaroo rats rarely live 2 years and only a few live through more than one breeding season. The population was composed of a few well-established individuals remaining continually on the area and a much larger number of animals which remained for only a few days or months.

The natural disappearance of kangaroo rats by month from Flat Area A is given in Table 4. Young and adults were tabulated separately through October

TABLE 3.—*Survival of 107 Dipodomys spectabilis captured on Flat Area A. The number of new rats taken in each period appears at the head of the appropriate vertical column. Survival in each of the following periods may be followed by reading down*

	1951			1952						1953						TOTAL
	Jul.*	Sep.* & Oct.	Nov. & Dec.	Jan. & Feb.	Mar. & Apr.	May & Jun.	Jul. & Aug.	Sep. & Oct.	Nov. & Dec.	Jan. & Feb.	Feb. & Apr.	May & Jun.	Jul. & Aug.	Sep.	Nov.*	
1951																
July*	6															6
Sept.*	5	35-3†														40
Oct.																
Nov.	3	22	3-*1*													28
Dec.																
1952																
Jan.	3	16	1	3												23
Feb.																
March	3	14-*1*	1	3	11											32
April																
May	2	12	0	3	6	15										38
June																
July	1	6-*1*	0	2	5-*1*	11	10									35
Aug.																
Sept.	1	4	0	2	4	9	8	3								31
Oct.																
Nov.	1	3	0	2	3	5	6	2	1							23
Dec.																
1953																
Jan.	0	3	0	2	3	4-*1*	4	2	1	1						20
Feb.																
March	0	2	0	2-*1*	3	3-*1*	4	2	1	1	5					23
April																
May	0	2	0	1	2	2	4	2	1	1	5	10				30
June																
July	0	1	0	1	1	0	2	2	0	1	4	4	2			18
Aug.																
Sept.	0	1	0	1	1	0	2	2	0	1	3	3	1	1		16
Nov.*	0	1	0	1	1	0	0	1	0	1	1	3	0	0	1	10

* Months in which the area was incompletely trapped.
† Figures in italics indicate number of animals dying in traps in that period.

in the table, but by November young were of adult size and were considered to be adults. Two periods of disappearance are apparent. The first period, April–June, coincided with the time in which most young become independent of their mothers. However, of the 42 individuals disappearing at that time only 13 were young, indicating that adults were disappearing more rapidly than young. The number disappearing in July and August was relatively small but increased again in the September–November period. In December–March, particularly the first months of the year when reproductive activity was most in-

TABLE 4.—*Natural disappearance of Dipodomys spectabilis from Flat Area A by months*

MONTH	FEMALES		MALES		ALL	
	Young	Adults	Young	Adults	Total	Per cent
Jan.	0	0	0	1	1	1
Feb.	0	0	0	1	1	1
March	1	2	0	1	4	5
April	1	2	1	2	6	7
May	4	4	0	2	10	12
June	3	6	1	6	16	20
July	3	0	0	0	3	4
Aug.	2	1	1	1	5	6
Sept.	1	1	5	0	7	9
Oct.	1	6	2	5	14	17
Nov.	0	4	0	6	10	12
Dec.	0	3	0	1	4	5
Total	16	29	10	26	81	99

tense, the populations seemed to be most stable with fewer new individuals appearing and few old animals disappearing from the area.

Reproduction.—Reproductive activity in the bannertail kangaroo rat began in December, the coldest month of the year, two to three months before the first visible signs of spring, and ended with the weaning of the last young by August. At the airport females gave birth to the first young of the season between their last captures in January and first captures in February. Outside of the airport a lactating female was captured on January 17. Table 5 gives the number of pregnancies observed each month at the airport. Pregnancies in live rats, diagnosed by sharp weight increases and palpation of embryos, could be determined only in the last two weeks of the gestation period. A few females may have evaded traps in this period and unless subsequently examined and found lactating produced unrecorded litters. All adult females regularly captured in the reproductive season had at least one litter each. Several females became pregnant more than once in a season. In 1952, 22 pregnancies were recorded for 13 females; six were pregnant once, five twice, and two three times. In 1953, 12 pregnancies were observed in nine females; six were pregnant only once, and three, twice. The frequent recapturing of females made it improbable that many pregnancies were undetected and the occurrence of more than three pregnancies in a female per season was doubtful. One female was pregnant three times in 1952 and once in 1953.

Usually the weight loss accompanying parturition increased even more in the following 3 to 4 weeks of lactation. Figure 3 illustrates continued weight loss in lactating females. The greatest post-parturition weight loss observed was 22.7 grams. These losses usually varied between 5 and 12 grams.

Swollen congested vulvas (indicating estrus?) occurred on only 14 occasions.

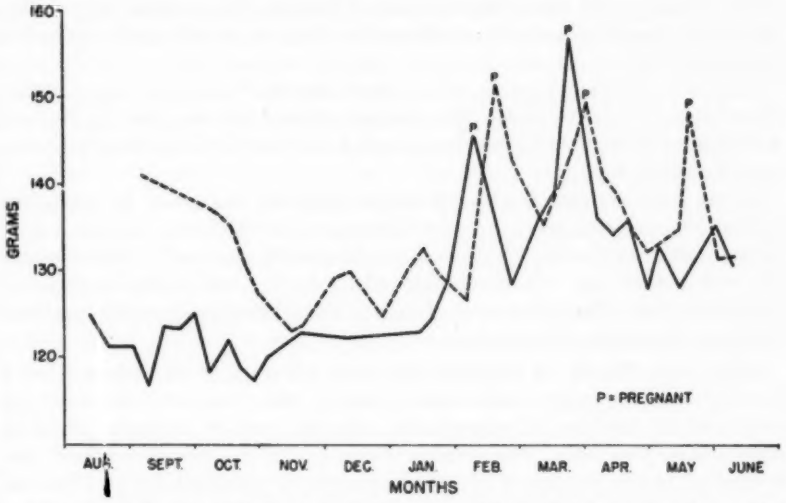

FIG. 3.—Weights of 2 adult female *Dipodomys spectabilis*. Weight increases were rapid in the last 2 weeks of the gestation period. Weight losses continued after parturition.

The paucity of records of swollen vulvas indicates that the period of swelling must have been brief or of inconsistent occurrence. The subsequent history of the 14 females with swollen vulvas follows: three were not observed again in the next six weeks and two others showed no indication of being pregnant in the following 64 and 87 days. The remaining nine females developed observable pregnancies from 21 to 49 days later. A stiff gelatinous material, probably formed after copulation, plugged the vulva of one of these females. Twenty-seven days later her weight had increased by 14 grams and she probably delivered young within the next ten days.

Bailey (1931) observed the gestation period in a captive *spectabilis*. He placed a male and female together on April 15 but vigorous fighting caused him to remove the male which was reintroduced to the female on April 20. Young were born on May 12. The maximum gestation period, in this case, would have been 27 days. If copulation, as he suggested, did not occur until after the second introduction of the male, gestation did not exceed 22 days. The data for *baileyi*

TABLE 5.—*Number of pregnancies in Dipodomys spectabilis captured at the airport*

NUMBER OF FEMALES		NUMBER OF PREGNANCIES						
Examined from Jan.–June	Pregnant	Jan.	Feb.	Mar.	Apr.	May	June	Total
1952: 22	13	4	4	5	4	4	1	22
1953: 10	9	1	3	4	1	3	0	12

in the present study, while inadequate to determine the gestation period since the actual days of copulation could not be determined, indicated a period in excess of 27 days.

The period between litters may have been only 5 to 7 weeks for some females. One female delivered a second litter between 42 and 49 days after her first and a third litter 37 to 42 days after the second. In each instance she must have conceived while lactating.

In the breeding season all adult males examined seemed to be producing sperm. The testes of seven measured in January and February averaged 17 × 10 mm. with extremes in length between 15 and 20 mm. and in thickness between 9 and 12 mm. Cauda epididymidis tubules could easily be observed microscopically. The testes were always in scrotal position but this condition persisted throughout the year in at least some males.

Litter size.—Nearly all kangaroo rats were live-trapped and released but a few females dying in live-catch traps or taken in other areas were dissected and examined for evidence of reproductive activity, such as embryos, placental scars and corpora lutea. The number of corpora lutea, when determined, corresponded to the number of observed embryos or placental scars. Three females delivered 2, 3, and 3 young, respectively, while captive in traps. Nine other females yielded the following information on litter size:

No. females	*Embryos or placental scars per female*
4	2
3	3
2	4

The 12 females either produced or probably would have produced 33 young for an average of 2.75 per litter.

Members of three litters, born in traps and weighed within 10 hours after birth, weighed as follows: 6.0, 8.0, and 8.5 grams; 7.3, 7.6, and 7.7 grams; 8.7 grams (one young not weighed); total weight of the seven young was 53.8; average weight, 7.7 grams. The weekly trapping schedule followed in this study often resulted in records of females pregnant in one week and lactating on the next capture the following week. Females delivering young between weekly captures lost weight varying from 6.4 to 53.9 grams and averaging 20.1 grams per female. The weight loss divided by the average weight of young at birth suggests an average of 2.6 young per litter.

Growth.—Young at birth were hairless, pink and wrinkled, with hind legs slightly larger than front, and tail only about one-half the length of body. They were unable to crawl but could squirm about. The ear pinna was folded down against the head and the eyes were closed.

Young born in the laboratory were marked and returned to the field with their mothers. One of these, a female, when captured 56 days later, had increased from 8.5 to 64.6 grams (Fig. 4). She was apparently independent of her mother

and occupied a previously deserted mound for the next 42 days. At the age of 108 days, weighing 95.2 grams, she moved again, this time to a location outside of the airport. Another female, pregnant on January 29 and lactating February 5, was captured with a young male (probably hers) on March 11. The young, from 35 to 42 days old, weighed 67.0 grams. A week earlier another young male (probably a litter mate of the former) captured at the same location weighed 57.9 grams. Figure 4 illustrates growth as indicated by weight increase for 2 young males. Young at first capture varied in weight between 47.1 and 120 grams; males weighed on the average 91.2 grams and females 93.3 grams. The weight of young at first capture indicated that they already had been active above ground for 2 to 3 weeks prior to entering traps.

Weight graphs, Figs. 5 and 6, show maximum, average and minimum weights of both young and old animals of each sex. Many individuals were weighed

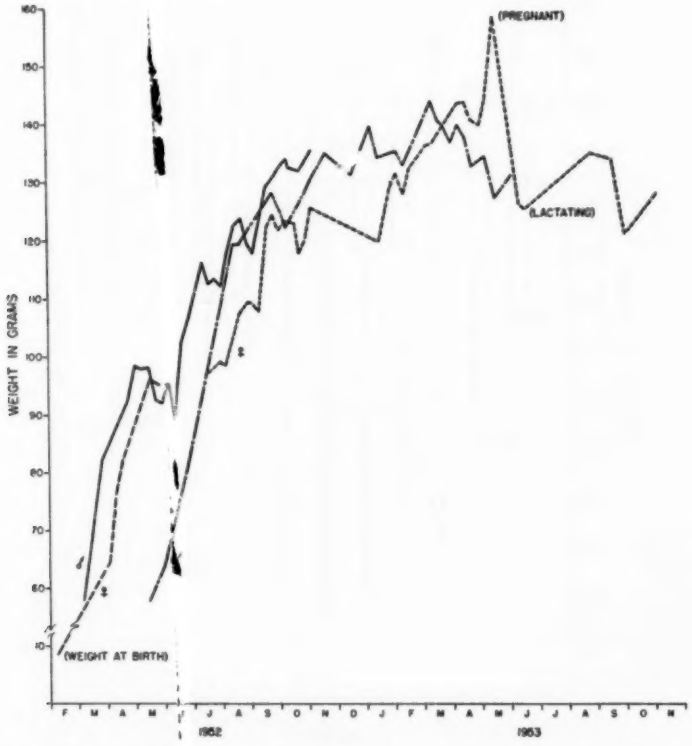

FIG. 4.—Weights of 2 female and 2 male *Dipodomys spectabilis* first captured as young. One female, first weighed at birth, was returned from the laboratory to the field with its mother. The others were active aboveground when first weighed.

more than once in a month. In these cases the weight records for each individual for the month were averaged and the average weight was used in calculation of the monthly group average. The procedure tended to reduce the spread between the maximum and minimum weights. For example, the extreme weight of a pregnant female nearing the end of the gestation period was usually obscured after combination with lower weights either before the last week of rapid gain or after the weight loss accompanying parturition. Young males grew faster than females and attained a larger size at maturity. The heaviest male weighed 177.8 grams, while females in the terminal period of gestation weighed as much as 176.7 grams. On the average, adult males weighed at least 5 grams more than adult females. After October, young of the year frequently weighed more than old adults and were considered to be adults.

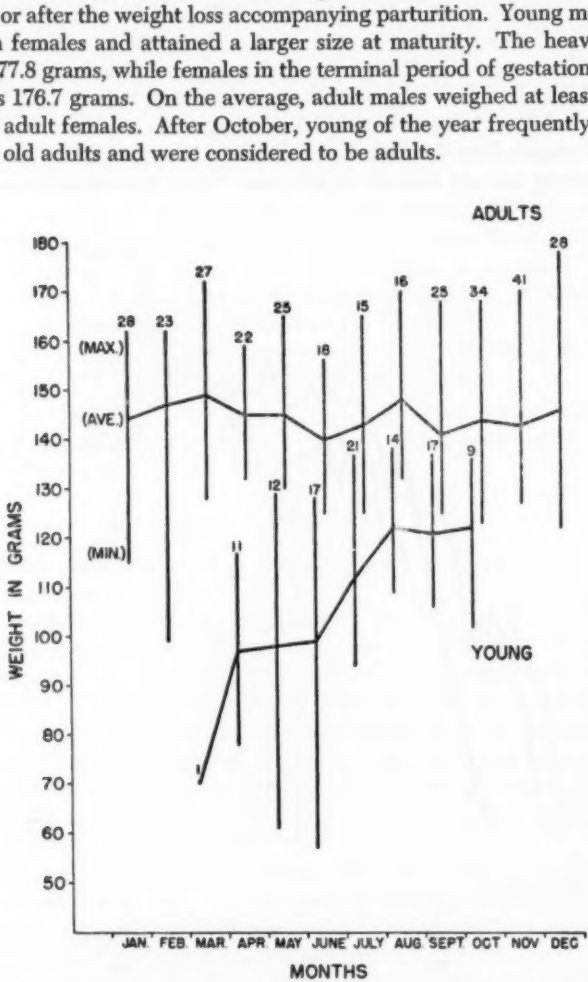

FIG. 5.—Summation of weights by month of *Dipodomys spectabilis* males. Numbers above vertical lines indicate number of individuals. The extreme minimum weight in January and February was reached by a rat with an undiagnosed fatal ailment.

Activity of dorsal dermal gland.—Both sexes possessed a large dorsal dermal gland situated posterior to the shoulders. The gland, active throughout the year, was raised above the surrounding skin and covered by a thin yellowish crust. Normally, the surrounding hair of wild-caught rats appeared neither stained nor matted, but on animals kept in small cages in the laboratory the hair soon became matted and appeared wet or greasy. Frequently kangaroo rats, when released from traps, briefly rubbed their backs on the ground before entering their burrows. This action may have been related to a function of the dermal gland either in leaving a scent on the ground or perhaps in dressing the hair. Young kangaroo rats on first capture had active dermal glands but newborn young lacked them.

Greatest distance between capture locations.—Repeated capture of kangaroo rats for long periods at locations separated by only a few hundred feet indicated a strong attachment of these animals to restricted home areas. Only ten

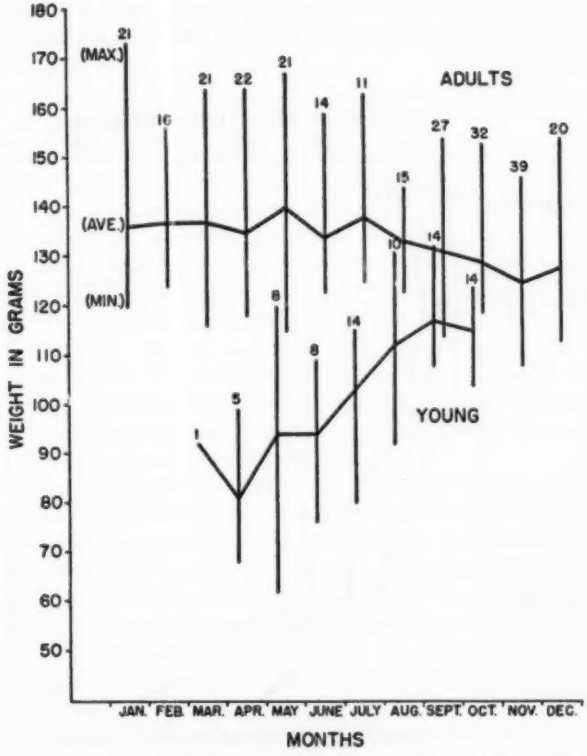

FIG. 6.—Weights of *Dipodomys spectabilis* females summarized by month. Figures above vertical lines represent numbers of animals weighed.

of the 130 retrapped individuals were recaptured at locations separated by more than 800 feet (Fig. 7). Seventy-nine per cent were always recaptured at locations separated by 600 feet or less. However, these rats were capable of rapid movement for long distances as illustrated by the capture of one adult male over a period of 18 days at locations separated by 4800 feet. He disappeared after the next capture, one week later, probably moving again. Other individuals made rapid moves to new locations. After completing these longer movements the individuals usually restricted their activity to small areas once more.

The delineation of home areas of animals by the recapturing of marked individuals has definite limitations. The relation of the number of recaptures of individual kangaroo rats to the greatest distance between captures is shown in Table 6. Individuals were usually not recaptured at less than weekly intervals. Each recapture, then, usually represents a minimum time interval of one week. As the number of captures increased, the length of time between first and last capture also increased. The longer the period of time a rat was studied the greater became the chances of encountering one or more shifts to new homes which, if away from the usual capture locations, increased the greatest distance between captures.

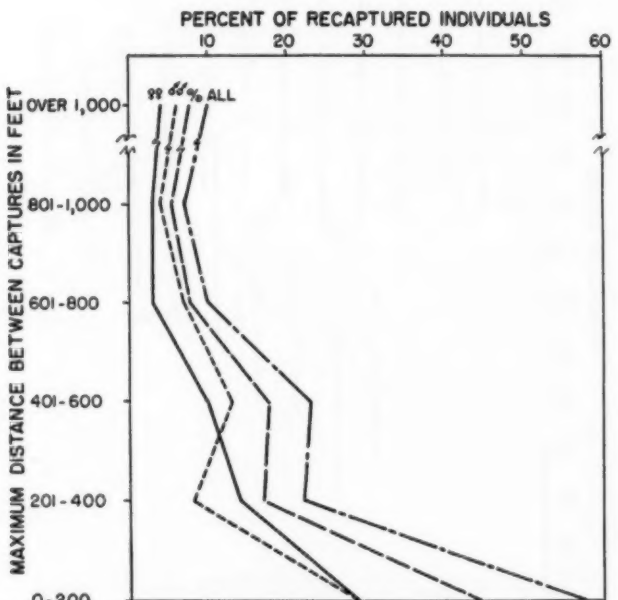

FIG. 7.—Maximum distances between capture locations of 130 *Dipodomys spectabilis* taken at the airport.

TABLE 6.—*Relation between number of recaptures and maximum distance between captures of Dipodomys spectabilis*

MAXIMUM DISTANCE BETWEEN CAPTURES IN FEET	NUMBER OF CAPTURES PER INDIVIDUAL							
	2–10	%	11–20	%	21–30	%	31–40	%
0–500	60	90	17	53	7	33	4	40
501–1000	5	7	13	41	10	48	4	40
Over 1000	2	3	2	6	4	19	2	20
Totals	67	100	32	100	21	100	10	100

Table 6 shows that 90 per cent of rats recaptured up to ten times were taken at locations separated by 500 feet or less. As the number of recaptures increased, a larger per cent of the individuals were captured at locations separated by 501 to 1000 feet. Regardless of the number of recaptures, the percentage of animals with capture locations separated by over 1000 feet remained small. Had the rats not restricted their activities to fairly local areas the proportion of animals with more than 1000 feet between capture locations would have increased more with each instance in the number of recaptures. Table 6 also shows that information on the size limits of the rat's range could be fairly well determined after eleven or more captures.

The average distance between the most widely separated capture locations for the 130 recaptured kangaroo rats was 465 feet. Sixty-two per cent of the individuals were captured at locations separated by 400 feet or less. Only 8 per cent were captured at locations separated by over 1000 feet and the individuals' presence at these widely separated points all followed definite moves to new homes, or the moves were made by wandering homeless animals. The study was not designed to determine the actual size of the area to which individuals restricted their activity. Rarely were animals captured away from burrows inhabited by *spectabilis* or well-traveled trails to which most of their activity must have been restricted. Information gained from the frequent retrapping of kangaroo rats demonstrated that they, like many other mammals, confine their activities to definite small local areas.

Movement of females following lactation.—Whether females left their homes after their litters became independent was not always known. There were 21 females with histories preceding and following 34 pregnancies or lactations. There was no noticeable change of homes by the mothers, but short moves to nearby new homes would not have been detected. Females disappeared after making long movements, in two instances, and these probably abandoned their homes after their young became independent. In seven instances, females disappeared from the trapping area six to nine weeks after young were born and may have moved from the area. Four females were recaptured for only two or three weeks after young were born and may have evaded traps, moved or died. Their young were not old enough to have been independent at the time of the mothers' last capture.

Actions after release from traps.—At times, trapped animals released in daytime seemed lost and dashed for cover of grass clumps or other vegetation. One animal, when released, made a dash from the trap to a cane cactus about 75 yards away. From the cactus it made a series of rapid circular dashes, returning to the cactus each time. In a few minutes, after a half dozen of these dashes, it seemed to become oriented and returned directly to its burrow just a few feet from the point of release. This type of action, consisting of rapid dashes from some cover, was observed frequently when the kangaroo rats were released from traps. Whether they eventually recognized their surroundings and were then able to locate their burrow, or whether they found a trail not obvious to the observer's eye and followed that to their burrow, was not determined. They were at times apparently lost in the daytime, even within 10 to 20 feet of their burrow, which was successfully located only after some search. Usually, however, the rats dashed for their burrow and cautiously disappeared into it.

Activity in relation to weather.—When an inch or more of snow covered the ground, kangaroo rats remained in their burrows, particularly if the temperatures were as low as 10° F. Trapping was a complete failure on several nights which were preceded or accompanied by cold weather and snow. After a day or two, even if the snow remained, activity increased. At such times burrow mounds, sometimes 300 to 400 feet apart, were connected by *spectabilis* trails, indicating that the rats visited neighboring burrows even under adverse conditions. Rains, except possible those of heavy intensity, did not prevent the animals from coming above ground. Winds rarely lasted through a night but some individuals were usually captured in spite of wind.

Activity in relation to darkness.—Kangaroo rats appeared to be strictly nocturnal but some individuals with earlier trap experience entered traps in the daytime. The majority became active at dusk or shortly after and entered traps within the first hours of darkness.

Predation.—Two species of snakes, one owl, and two carnivorous mammals were present on the study area, but no observations of actual predation on kangaroo rats were made.

One or more badgers, *Taxidea taxus,* were present at the airport throughout the period of study. Badgers dug into *spectabilis* mounds frequently. One marked kangaroo rat was not recaptured after its mound was opened by a badger; it must have been eaten or forced to move. However, some kangaroo rats did not even abandon mounds opened by this carnivore. A coyote, *Canis latrans,* was seen at the airport for a few weeks one winter but this species was rare in the area. Horned owls, capable of preying on kangaroo rats, were present during much of the study period.

Rattlesnakes and gopher snakes both were active over the area for about nine months of the year. They were most frequently seen in or near *spectabilis* mounds. The intestinal contents of those examined did not contain identifiable kangaroo rat remains, though many of the snakes seen were large enough to swallow these rodents easily.

Surveillance for disease.—Ectoparasites removed from all mammals trapped at the airport in one week of each month were bacteriologically tested for plague and tularemia organisms by the San Francisco Field Station of the Communicable Disease Center. Mammal ectoparasites from other locations in Santa Fe County were also tested. No disease organisms were found in parasites from the airport mammals nor in kangaroo rat parasites from other locations. Kangaroo rats were absent from a canyon, 10 miles from the airport, in which plague-infested fleas were found on *Reithrodontomys megalotis, Peromyscus maniculatus, P. leucopus, P. truei, Neotoma albigula* and *Citellus variegatus* (Holdenried and Morlan, 1955). Direct relation of kangaroo rats in the field to plague was not observed but the attraction of other rodents to their mounds may offer a site from which disease could spread.

Twenty-one species of rodents captured in the Santa Fe area were tested in the laboratory for susceptibility to plague (Holdenried and Quan, 1956). Among the experimental rodents were 13 *spectabilis* which were inoculated intracutaneously with up to 10^7 organisms (approximately a million white mouse LD50). Of the 21 rodent species tested, *D. ordii* and *D. spectabilis* were the least susceptible to experimental infection. Kangaroo rat popu'ations, of at least the two tested species, should be less affected by plague epizootics than those of the more susceptible associated rodent species. Although the Santa Fe studies terminated before desired additional information was obtained, the possibility should not be overlooked that *spectabilis*, with its heavy flea infestations (Morlan, 1955) and its resistance to lethal infection, may act as a reservoir for the infection.

SUMMARY

1. From July, 1951, to November, 1953, the bannertail kangaroo rat was studied near Santa Fe, New Mexico, primarily by recapturing marked individuals.

2. The large mixed earth and chaff mounds, honeycombed with burrows built by the bannertail kangaroo rat, formed localized sites attractive to *Dipodomys ordii, Perognathus flavus, Citellus spilosoma, Onychomys leucogaster* and *Sylvilagus audubonii*. These sites offered a possible point for transfer of disease and ectoparasites among the various species of mammals.

3. A total of 172 kangaroo rats were live-trapped. Of these, 107 were taken on a special 43-acre study area. The population was highest (average of 0.9 per acre) in 1951 and lowest (0.4 per acre) in the fall of 1953. While reduced plant growth and fruiting resulted from slight and spotty precipitation in 1953, kangaroo rats showed no evidence of starvation.

4. Nearly equal numbers of both sexes occupied the area.

5. Some kangaroo rats lived in small restricted locations for most or all of their lives; others lived in restricted locations, then moved and established new homes. Long moves of over 1000 feet were made by both young and adult individuals.

6. Reproductive activity began in December. Young were born from January through June. Litter size varied from one to four young, averaging from two to three young each. The maximum number of pregnancies observed in one female was four (3 in the first year, 1 in the next). Most females had only one or two litters in a season.

7. Young at birth weighed from 6 to 9 grams each. They were active aboveground at an age of about 5 weeks, after approximately a tenfold weight increase. A young female was independent of its mother at the age of 2 months. On reaching adult size, growth ceased and weights tended to remain fairly stable. Males grew faster than females and, on the average, were heavier.

8. In the reproductive season, females with swollen and congested vulvas were occasionally observed; the significance of this in the reproductive cycle was not determined.

9. Ectoparasite collections bacteriologically tested showed no evidence of plague or tularemia organisms.

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THE RELATIONSHIP OF *PETROMYS* TO THE OCTODONTIDAE

By Stuart O. Landry, Jr.

Allusions appear frequently in the literature to the idea that a special relationship exists between the African hystricomorph rodents *Petromys* and *Thryonomys* and the Octodontidae and Myocastoridae (Capromyidae *auct.*), respectively, of South America. I have elsewhere (*In press*) reviewed the history of this arrangement and attempted to show that few positive reasons for classifying these two genera with South American families have ever been advanced. The idea derives ultimately from the unsupported assertion of Waterhouse (1839).

Ellerman (1940) classified both *Petromys* and *Thryonomys* as sole representatives of the subfamilies Petromurinae and Thryonomyinae of the Echimyidae. This "Echimyidae" is roughly the equivalent of Simpson's (1945) "Octodontoidea," so these two authors really classified *Petromys* and *Thryonomys* in the same way, as Simpson lists them under Petromyidae and Thryonomyidae of the Octodontoidea, stating (p. 212), "... *Thryonomys* and *Petromys* are morphologically octodontoid and it has been common practice to refer them to neotropical families and subfamilies, for instance, placing *Petromys* with *Octodon* and *Thryonomys* with *Capromys*."

Wood (1955) separates *Thryonomys* and *Petromys* from the South American hystricomorphs in his splitting apart of the suborder Hystricomorpha. He divides the hystricomorphs into two suborders: Hystricomorpha (Old World forms) and Caviomorpha (New World forms). He still asserts, however, that there is "morphological similarity" between *Petromys* and *Thryonomys* and New World families. He says (p. 184), "There are many obvious similarities to the Octodontidae and Echimyidae respectively. These are so great that formerly the African genera were placed in South American families. This is still done sometimes, the latest example being Ellerman, Morrison-Scott and Hayman (1953: 237–239) who consider the Thryonomyinae, Petromurinae and Echimyinae to be subfamilies of the Octodontidae."

As a matter of fact, Ellerman, Morrison-Scott and Hayman (1953) concede that there may be some doubt about the classification of *Thryonomys*, but they cling fast to Ellerman's placement of *Petromys*. They remark (p. 225), "Some American authors and others dislike referring the Thryonomyinae and Petromurinae to an otherwise South American family Octodontidae (or Echimyidae) [Octodontoidea of Simpson] on account of the fact that they feel African and South American genera cannot be allied. *Thryonomys* is a distinct genus and perhaps merits family rank but the same cannot be said of *Petromus* which is essentially morphologically an octodontid and these authors usually ignore the fact that if *Petromus* is separable on a subfamily level from the South American Octodontinae, it is hard to separate the South African genus *Mystromys* even on a generic level from some of the South American forms which it closely resembles."

In the first place, few people dislike referring *Thryonomys* and *Petromys* to a South American family "because they feel that African and South American genera cannot be allied." No one is disturbed by the fact that *Panthera* (which, indeed, may be a subgenus) is found today in Africa and South America. The point is, of course, that the South American hystricomorphs evolved in South America at a time when that continent was separated from the rest of the world. The reconnection of North and South America took place in the late Pliocene. In order to get to Africa, the Octodontoidea (*quondam* Octodontidae, *quondam* Echimyidae, *quondam* Echinomyidae) would either have to have had a holarctic distribution in the Pleistocene (as did *Panthera*) or to have rafted across the South Atlantic. "American authors and others" consider either of these possibilities remote. In the second place, difficulties in classifying *Mystromys* cannot have the slightest bearing on the classification of *Petromys*.

At any rate, Ellerman, Morrison-Scott and Hayman also take for granted that *Petromys* is morphologically similar to the South American Octodontoidea. All of these authors, then, believe that there is strong morphological evidence for uniting *Petromys* and *Thryonomys* with the South American Octodontoidea whether or not the animals are so classified.

I have elsewhere (*In press*) contended that this superfamily is an unnatural group, that it is the remnant of the Hystricomorpha after all natural groups have been removed. If I am correct in this, then the "affinities" of the two African forms to the "Octodontoidea" mean merely that we know too little about *Petromys* and *Thryonomys* to classify them.

This disposal of the problem is not quite sufficient, however, because specific affinities between *Thryonomys* and *Capromys* and between *Petromys* and the octodonts have been alleged (Waterhouse, 1839; Alston, 1876; Flower and Lydekker, 1891). I have already discussed the alleged resemblances between *Thryonomys* and *Capromys* (*In press*) but I was not able at that time to compare *Petromys* thoroughly with the various genera of the Octodontidae (*sensu stricto*). The improbability of a relationship between *Petromys* and the octodonts was pointed out by Tullberg (1899: 382) but the passage does not seem to have attracted much attention. A thorough comparison of the skulls of *Petromys* and the octodonts is long overdue, for the old idea of a specific relationship between these forms remains in the literature. Even those who only relate *Petromys* to the same superfamily (family of European authors) as the octodonts are, I suspect, unconsciously influenced by the old notion that *Petromys* resembles *Octodon*.

The purpose of this paper is to compare the skulls of the six living octodontid genera with that of *Petromys* and to point out morphological characters common to the several South American genera and absent from *Petromys*, and characters present in *Petromys* but absent from the octodonts. This procedure will not prove that *Petromys* is unrelated to the octodonts, but it will show that *Petromys* is rather different from them and will throw the burden of proof on those who wish to contend that *Petromys* is an octodont.

Since great confusion surrounds the use of the word "Octodontidae," I have used the word "octodont" in this paper to encompass the six living genera of Andean rodents, whose cheek teeth are hypsodont, rootless, and greatly simplified in occlusal pattern. "Octodonts" are thus the equivalent of the Octodontinae of Ellerman (1940), the Octodontidae and Ctenomyidae of Simpson (1945) and of Wood (1955). They are the equivalent of my Octodontinae (1957) and do not include the genus *Abrocoma*, which is at best an aberrant octodontid and may not pertain to the family at all.

I have used the name *Petromys* and its derivative "Petromyidae" in this paper since these are the forms in common use. They are, however, probably invalid. I have no first-hand knowledge of the situation but as I understand it from Wood (1955) and Simpson (1945), the validity of *Petromys* hinges on whether, in the original description (Smith 1831), the name *Petromus* is a typographical error, or whether Smith simply changed his mind and later called the animal *Petromys*. I must agree with Ellerman (1940) and Wood (1955) that the latter interpretation is more probable. I am, however, reluctant to abandon a name that was in almost universal use for 110 years. Perhaps this is another case for suspension of the rules by the International Commission.

Acknowledgments.—My thanks are due to the authorities of the following institutions for the loan of specimens: The Museum of Comparative Zoology at Harvard; the American Museum of Natural History; the Chicago Natural History Museum; and the Museum of Vertebrate Zoology, University of California. I am additionally indebted to the authorities at M.C.Z., the American Museum, and the Chicago Natural History Museum for their courtesy in allowing me free use of their facilities and specimens during my visits there. Finally, it is a pleasure to acknowledge the assistance of Mrs. Geneva S. Williams, who prepared the illustrations for this paper.

Observations and conclusions.—The skulls of the six living genera of octodonts, *Ctenomys, Spalacopus, Octodon, Aconaemys, Octomys* and *Octodontomys,* comprise an interesting example of adaptive radiation. The three "central genera," *Octodon, Aconaemys* and *Octodontomys,* are primitive rat-like forms although they are quite different from each other. The other three are more specialized. *Ctenomys* and *Spalacopus* are both burrowing forms, but they are adapted for burrowing in different ways. *Ctenomys* resembles the North American pocket gophers (geomyids), mostly using its long claws for digging, and having a stout broad skull with massive incisors. (Figs. 1, 3). *Spalacopus* parallels the African Bathyergidae, using its long, greatly protruding incisors for digging and having a slender skull with a reduced rostrum (Fig. 2). The claws of *Spalacopus* are relatively weak.

Octomys has greatly enlarged auditory bullae. This enlargement distorts the occipital region of the skull and gives a distinctive appearance to the skull of this octodont. According to Thomas (1920) both *Octomys* and *Octodontomys* superficially resemble the African gerbils.

The octodonts are thus quite varied in skull structure and common characters

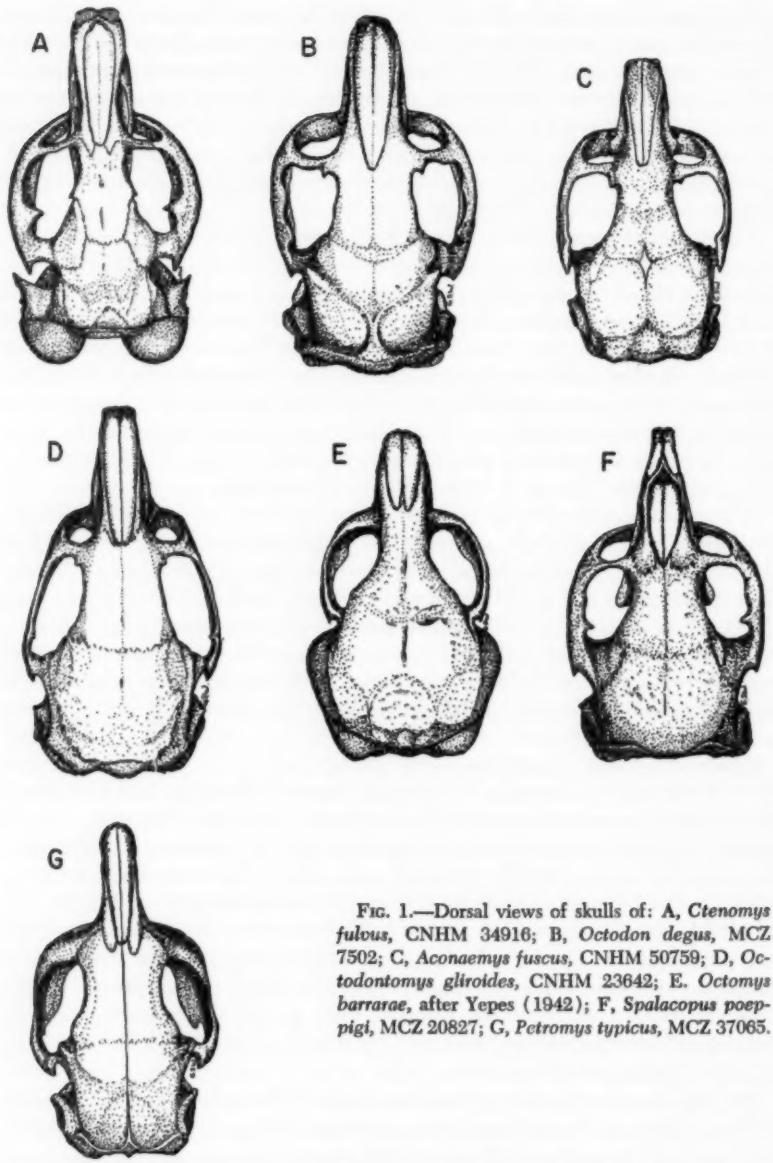

FIG. 1.—Dorsal views of skulls of: A, *Ctenomys fulvus*, CNHM 34916; B, *Octodon degus*, MCZ 7502; C, *Aconaemys fuscus*, CNHM 50759; D, *Octodontomys gliroides*, CNHM 23642; E. *Octomys barrarae*, after Yepes (1942); F, *Spalacopus poeppigi*, MCZ 20827; G, *Petromys typicus*, MCZ 37065.

are apt to be difficult to find. The common feature for which the octodonts are named is the possession of rootless, ever-growing cheek teeth, with single,

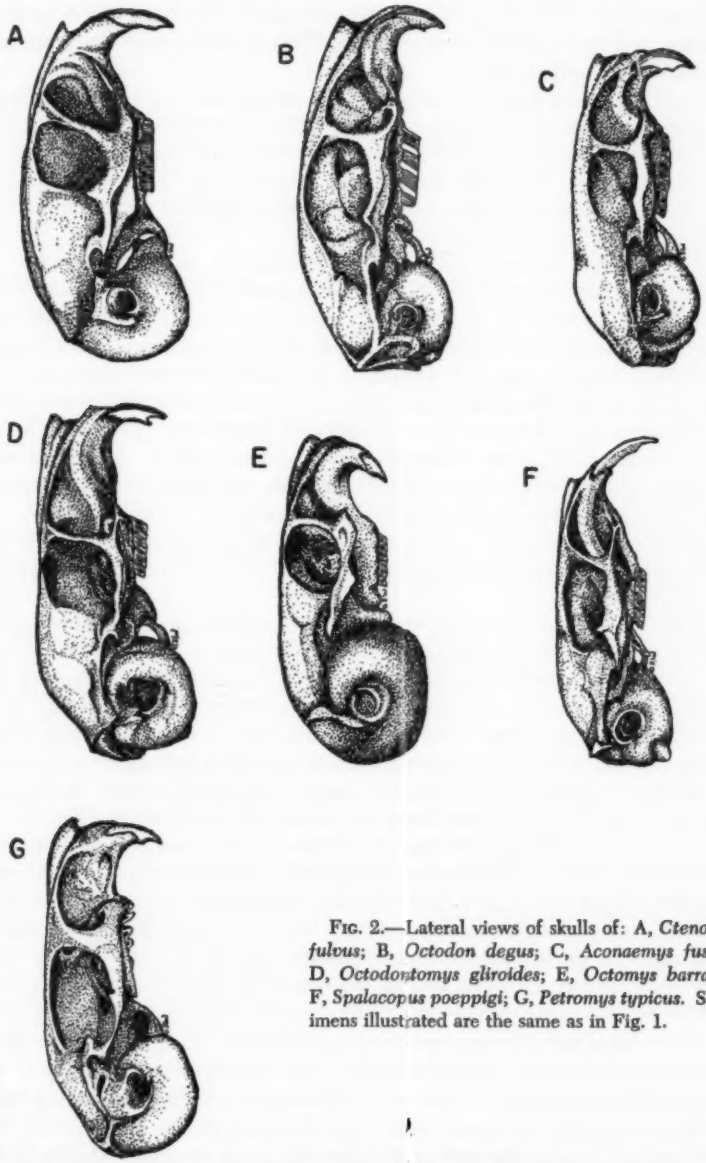

FIG. 2.—Lateral views of skulls of: A, *Ctenomys fulvus*; B, *Octodon degus*; C, *Aconaemys fuscus*; D, *Octodontomys gliroides*; E, *Octomys barrarae*; F, *Spalacopus poeppigi*; G, *Petromys typicus*. Specimens illustrated are the same as in Fig. 1.

broadly-opening external and internal infolds, so that the surfaces of the teeth resemble figure eights (although at times the resemblance is obscure, Fig. 3).

The cheek teeth of *Petromys* in occlusal view have something of the same appearance, and some authors have concluded that for this reason *Petromys* must be related to the octodonts.

I would not attach much importance to the resemblance in occlusal tooth pattern between these forms because similar patterns are widespread among rodents. Occlusal cheek tooth patterns not very different from those of the octodonts may be found in such disparate forms as *Georychus, Ctenodactylus, Dipus* and *Pedetes*. I would not consider this point very important unless there were corroborative evidence in other characters.

Actually the cheek teeth of *Petromys* are rather different from those of the octodonts. In *Petromys*, the cheek teeth are hypsodont but they are not rootless as are the cheek teeth of all known octodonts, fossil and Recent. Even more important is the fact that in *Petromys* alone, of all hystricomorphs, the surfaces of the cheek teeth are not flat (Figs. 2, 3, 4). Distinct enamel cusps are to be found at the outer side of the upper teeth and the inner side of the lower teeth. They thus correspond to the type of tooth that Hershkovitz (1955) calls "terraced" in cricetines (see Tullberg, 1899; Landry, 1957). Far from supporting an affinity of *Petromys* with the octodonts, a comparison of the structure of the cheek teeth argues against such a relationship.

In addition to this p[illegible]ich I have previously discussed) the following specific differences between the skulls of octodonts and that of *Petromys* may be cited:

1. The bony palate of all octodonts ends between the cheek-tooth rows, never reaching farther back than the junction of the second and third molars and, in *Octodon*, ending considerably farther forward. This erosion of the bony palate is not found in *Petromys*, where the palate ends behind the tooth row (Fig. 3). Prolongation of the choana between the tooth rows is not uncommon among rodents, but it is certainly a primitive octodont character missing from *Petromys*.

2. In the octodonts the skull tends to narrow between the orbits. In *Petromys* the skull is broad with little tendency for interorbital constriction (Fig. 1).

3. In the octodonts the anterior end of the ventral anterior zygomatic root lies well forward of the anteriormost cheek tooth. In *Petromys* the anterior edge of the alveolus of P^4 lies close to the leading edge of the ventral anterior zygomatic root and sometimes anterior to it. I have not found the cheek teeth so far forward (or the ventral anterior zygomatic root so far back) in any other rodent. The closest approach among the octodonts is in *Ctenomys*, but even here the cheek teeth are well behind the front end of the zygomatic root (Fig. 3).

4. The ventral anterior zygomatic root in octodonts is anterior to the dorsal anterior root (as in most hystricomorphs). The two anterior roots lie in almost the same transverse plane in *Petromys*. *Octomys* may be an exception judging from the photographs in Yepes (1942, from which my figures are copied). The ventral anterior zygomatic root is in about the same position, relative to the dorsal, as in *Petromys* (Figs. 2, 3).

This character may seem to be only a corollary of the last but it is not. In

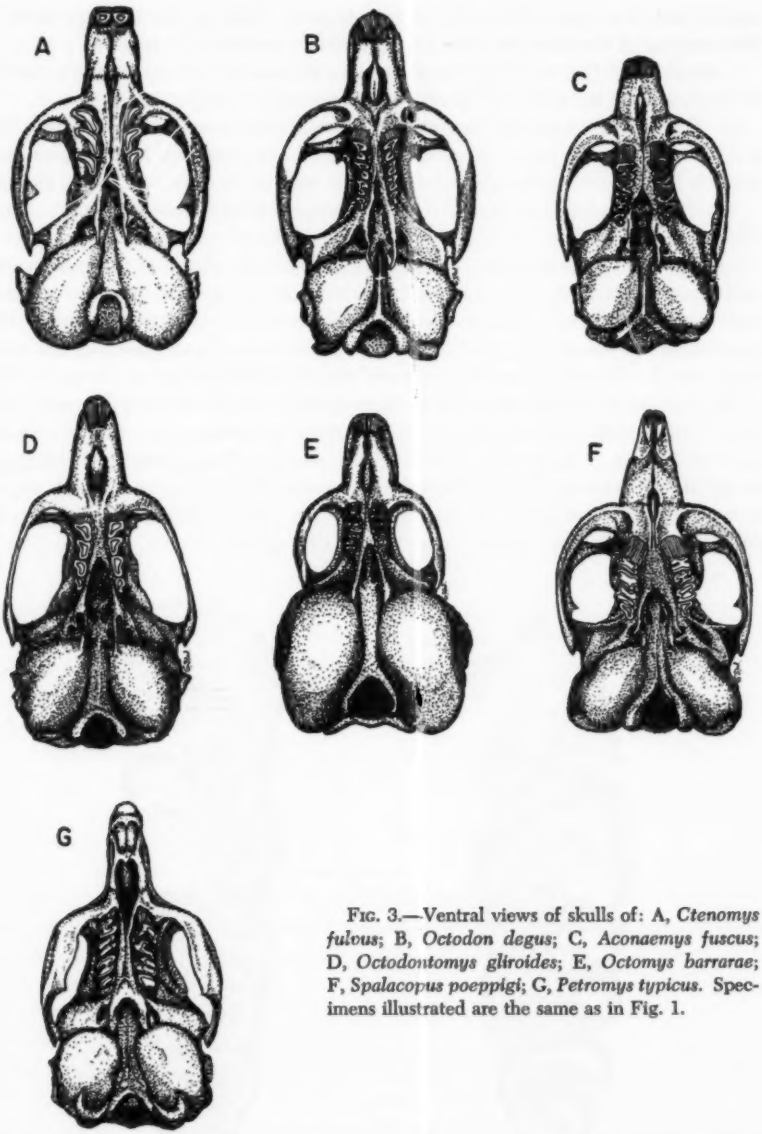

FIG. 3.—Ventral views of skulls of: A, *Ctenomys fulvus*; B, *Octodon degus*; C, *Aconaemys fuscus*; D, *Octodontomys gliroides*; E, *Octomys barrarae*; F, *Spalacopus poeppigi*; G, *Petromys typicus*. Specimens illustrated are the same as in Fig. 1.

Trichys and *Atherurus* (primitive Old World porcupines) the ventral anterior zygomatic root is actually posterior to the dorsal, yet the cheek teeth are well behind the leading edge of the ventral root. The positions of the dorsal and

ventral anterior zygomatic roots relative to each other are thus independent of the position of the cheek teeth relative to the ventral root in rodents.

I should add the warning that these two characters are not always evident in figures. One must check the characters on actual skulls.

5. The incisive foramen varies in size somewhat among the octodonts but it is never extremely large. The incisive foramen in *Petromys* is very large, and extends back between the cheek teeth to the middle of the first molar (Fig. 3).

6. The skull of *Petromys* is flattened dorso-ventrally more than that of any octodont or indeed of any hystricomorph that I know. One easily visible consequence of this flattening in *Petromys* is a distinctive shape of the infraorbital foramen. The transverse dimension of the foramen is greater than the vertical, whereas, among the octodonts and all other hystricomorphs, the vertical dimension of the foramen is greater than the transverse. The foramen of the octodonts may be thought of as "standing up" and that of *Petromys* as "lying down."

The above six characters suffice to show that the octodonts and *Petromys* represent rather different lines of rodent evolution. Any characters that they have in common (e.g., a mastoid widely exposed between the paramastoid and paraoccipital processes of the supraoccipital) seem to be general among rodents, or at least among hystricomorph rodents. On the other hand, specializations in the skulls of these two groups appear to be divergent.

FIG. 4.—Left upper tooth rows of *Petromys typicus*, MCZ 37065 (left), and *Octodon degus*, MCZ 7502 (right). Note raised inner cusps in *Petromys*.

The statement that the skulls of *Petromys* and octodonts are morphologically similar is a misleading half-truth. The question is, how similar? In a sense all rodent skulls are similar. Undeniable similarities are seen in the skulls of *Petromys* and the octodonts, but if one implies by the statement that these skulls are "similar" that they share distinctive specializations that could be used as evidence for relationship, then the statement is false. No such taxonomically important similarities exist.

The science of taxonomy consists not so much of amassing common characters as of assessing them. The idea that *Petromys* is an African octodont remains with us only because no one has troubled to assess the common characters of Octodonts and *Petromys*. From what I can see, any similarities between the skulls of *Petromys* and those of the octodonts can be easily explained as heritages from the common ancestral rodent. Thus, there are no conspicuous parallelisms between *Petromys* and the octodonts.

Another group of South American forms with which *Petromys* is sometimes classified is the Echimyidae (*sensu stricto*), the spiny rats. In some of the characters above, where *Petromys* differs from the octodonts, it resembles the echimyids. The bony palates of some echimyids (e.g., *Dactylomys*) end behind the cheek teeth as in *Petromys*, and the skulls of echimyids, like that of *Petromys*, are wide with little tendency to narrow between the orbits.

These similarities are primitive rodent characters and are not taxonomically significant. Tullberg (1899) placed *Petromys* in the Echinomyidae (Octodontoidea of Simpson) but not with the Echinomyini (Echimyidae of Simpson). The passage is not clear (pp. 381–382) but I infer from it that Tullberg also regarded the similarities between *Petromys* and the spiny rats as due to a common retention of primitive characters.

As I shall discuss in a future paper, one of the few genuine specializations that I have found in the skulls of echimyids (ignoring the teeth) is a backward prolongation of the occiput, so that the superior nuchal line overhangs the foramen magnum. I can see nothing of this in *Petromys*.

The above evidence is sufficient to show that there is no special morphological affinity between *Petromys* and the South American hystricomorphs. Certainly there are rather sharp differences between these animals; in view of the zoogeographical difficulties that a relationship between them would bring up, I think we may dismiss the idea.

I emphasize again that the differences cited above do not prove that *Petromys* could not be an octodont. It could be, but *could be* and *is* are quite different. Nothing is easier than to demonstrate that two animals could be related to each other and nothing more meaningless. We are not interested in whether animals *could be* related to each other. We are interested in assessing the probabilities that they *are* related. On the basis of comparative skull morphology, it is improbable that *Petromys* is an octodont.

It seems safe to conclude, therefore, that the impressive morphological sim-

ilarity between *Petromys* and the South American forms that has so long haunted the literature on hystricomorph rodents does not exist.

Summary.—The African genus *Petromys* has often been classified with the South American octodonts (*Ctenomys, Spalacopus, Octodon, Aconaemys, Octomys* and *Octodontomys*). The chief reason for this seems to be a resemblance in occlusal pattern of the cheek teeth. Actually, the cheek teeth of *Petromys* are very different from those of the octodonts or any other hystricomorph rodent. The inner sides of the upper and outer sides of the lower cheek teeth are raised, to form cusps, which restrict the grinding motion of the jaw to the transverse direction. Octodonts have completely flat-crowned molars. In addition, the following six differences between the skulls of octodonts and that of *Petromys* are noted:

1. Bony palate of octodonts ends between tooth rows. Bony palate of *Petromys* ends well behind tooth rows.
2. Octodont skulls tend to narrow between the orbits. The skull of *Petromys* is broad between the orbits.
3. In *Petromys*, the anteriormost cheek tooth alveolus is on a line with, or anterior to, the leading edge of the ventral anterior zygomatic root. In octodonts, the cheek teeth are well behind the zygomatic root.
4. Ventral anterior zygomatic root is anterior to the dorsal in octodonts; on a line with the dorsal in *Petromys*.
5. Incisive foramen penetrates between cheek teeth in *Petromys*, not in octodonts.
6. Skull of *Petromys* flattened. Transverse diameter of infraorbital foramen greater than ventral. Skulls of octodonts not flattened, vertical diameter of infraorbital foramen greater than transverse.

It is concluded that there is no morphological evidence for uniting *Petromys* with the octodonts.

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EFFECTS OF CHRONIC INSUFFICIENCY OF DRINKING WATER IN WHITE MICE

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Previous dehydration studies have emphasized almost exclusively acute dehydration in white rats or larger laboratory mammals. There is little information on rodents smaller than rats, or on the effects of chronic dehydration on any sized mammal. In order to study dehydration uncomplicated by other changes, such as starvation, it may be necessary to cause water loss quickly—by forced diuresis (see Brokaw, 1949) or forced extrarenal loss by exposure to heat (Adolph, 1947). But, as pointed out by Brokaw, an animal's response to and toleration of a rapidly developing dehydration may be quite different from that of a slowly occurring water loss.

There are fairly numerous reports of casual, limited observations of the general effects of water deficiency on small wild rodents (see review by Schmidt-Nielsens, 1952), but there have been few serious studies. The latter include studies of survival time on reduced water rations (Lindeborg, 1952), measurement of energy metabolism and water exchanges on extremely reduced water intakes (Chew, 1951), and measurement of water balance and kidney function in rodents on air-dry diets (Schmidt-Nielsens, 1952). Changes in the blood and in the water compartments of mice on restricted water intakes is an unexplored field.

The physiological effects of inadequate water intake or excessive water loss are varied: starvation (Adolph, 1947; Brokaw, 1949), reduction in blood volume, with edema (Dicker, 1949) or without edema (Adolph, 1947), failure of renal responsiveness to water load (Dicker, 1949), concentration of body fluids (Black *et al.*, 1944), and cell dehydration (Winkler *et al.*, 1944). Death that may occur during dehydration has been attributed to circulatory collapse (Adolph, 1947; Brokaw, 1949) and cell dehydration (Black *et al.*, 1944; and others), but not to starvation, although starvation has been mentioned as a complication.

The object of the present study has been to determine the effects of relatively

long-term water insufficiency (17–38 days), the type of deficiency that can be expected to occur in nature, rather than a sudden lack of water. The extent of body dehydration, depletion of fat-energy stores, and blood changes have been followed in order to delimit the factor(s) most critical in causing death. These changes have been followed in a group of mice of mixed ages and both sexes, simulating a natural population structure.

METHODS, MATERIALS AND PROCEDURE

General.—White mice were used for the present experiments so that sufficient numbers of mice of known age would be easily available. The mice used were offspring through three generations of the same parental pair, and so had a relatively uniform inheritance.

Figure 1 shows graphically the plan of the experiments. Each bar represents a group of eight mice, while each segment of a bar indicates the duration of a particular level of drinking water intake.

The five groups of mice used in 1954 contained equal numbers of males and females. Each group also contained mice of three different ages—mice 13, 3½–4, and 2⅛ months old respectively at the start of the experiments on March 24. The ratio of these ages in the experimental population as a whole was 2:2:1. The four groups used in 1955 contained only female mice, 5–8 months old at the start of the experiments.

At each point marked *x* a group or part of a group was killed and total body water content, total body lipid content, and blood water content were measured for each individual. At points *b* samples of blood were taken from each mouse, and water content, specific gravity

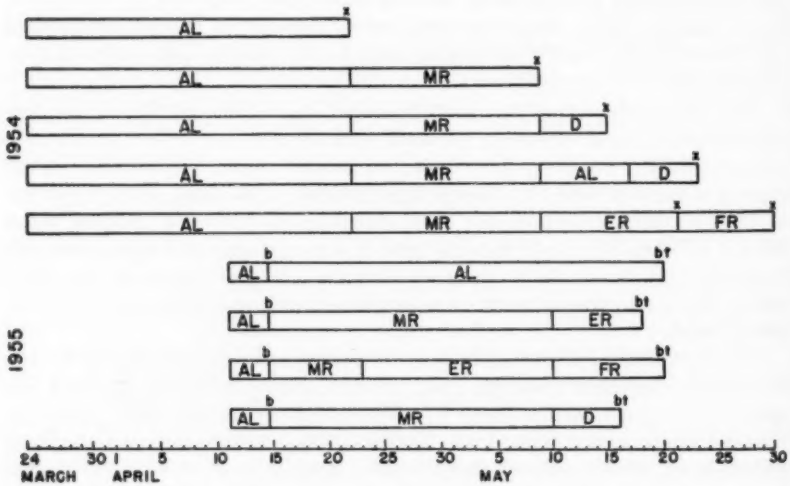

FIG. 1.—Graphic representation of plan of experiments. Each bar represents a group of eight mice; each segment indicates the duration of a particular water regimen. AL—*ad libitum* intake, MR—moderate restriction to 49.7–32.4% *ad libitum*, ER—extreme restriction to 16.8% *ad libitum*, D—deprivation, no water; x—sacrifice of group for analysis, b—blood samples taken, bt—blood and organ samples removed.

and hematocrit measurements were made on the samples. At points *bt* blood samples were taken, and then hind leg muscle and liver samples were removed for water and fat analysis.

During the course of the experiments the mice were kept in individual cylindrical cages 4 inches wide and 4½ inches high. Water was provided in Pyrex culture tubes, the open ends of which had been narrowed to 2–3 mm. Purina Chow was provided in a hopper in a detachable side compartment of each cage. A spillage tray attached to each compartment caught most of the crumbs dropped by the mice.

Water rations were measured into the drinker tubes from a 100-ml. burette calibrated in 0.2-ml. units. When the mice were allowed to drink as much as they desired, water intake was measured as the amount of water needed to completely refill a tube at the end of a 24-hour period. At less than *ad libitum* levels of intake, definite amounts of water were measured into empty tubes before they were placed in the cages. The measured amounts were always completely drunk by the mice. Evaporation from the tubes was not significant.

Food consumption was measured by weighing the detachable food hoppers at the beginning and end of each feeding period. Food and water intake were measured daily; body weight was usually measured every other day, but was measured daily for certain short periods.

The caged mice were kept together in groups of eight cages on a table-top in a well-ventilated laboratory room. Temperature and relative humidity were recorded continuously, and these factors were satisfactorily consistent through different phases of the experiments and between the two years. The climatic data are shown in the tabulation below:

	1954	1955
Mean of ave. daily air temps. (range), ° C	21.53 (19.8–25.6)	21.96 (20.0–24.2)
Mean daily minimum	20.35	20.91
Mean daily maximum	22.72	23.46
Extreme range	17.8–26.7	17.8–26.1
Mean of ave. daily vapor pressures (range), mm. Hg	8.90 (5.0–10.8)	11.14 (9.5–12.8)
Mean vapor pressure deficit with respect to 37° C	27.67	35.56
Index of water loss by mouse in saturating breathed air*	1.38 gm./day	1.31 gm./day

* Values calculated assuming a mouse with energy expenditure of 4.74 Cal./day, 12% utilization of inspired oxygen, 4.825 Cal./liter of oxygen utilized, air saturated at 37° C.

Measurement of body water and lipid contents.—After the fresh weight of a dead mouse had been measured, the mouse was cut up into small pieces and then homogenized in a Waring blendor. The homogenate was divided between two 150-ml. beakers and dried to a constant weight in an oven at 100–102° C. After the dry weight was determined, the lipids in the dry material were extracted in a Soxhlet apparatus for eight hours, using Skelly B petroleum ether as the solvent. The ether was removed from the extract by distillation and the residue was dried in an oven for 24 hours at 100–102° C. Fat-free weight was calculated as: dry weight – weight of extracted lipids.

Several control samples desiccated by lyophylization rather than by oven heating showed that oven-drying caused some charring and volatilization of lipids (lipid content of oven-dried aliquots averaged 0.3 per cent less than lyophylyzed aliquots), but the loss by volatilization was not sufficiently significant to warrant the additional labor of lyophylyzing the homogenized mice.

Technique checks indicated that mice need not be eviscerated or clipped of their fur before analysis, as was done by Rathbun and Pace (1945) when working on the water and fat contents of guinea pigs. Five *ad libitum*-fed mice killed at 8 AM were compared with five mice killed at 8 AM after 16 hours without food, and there was no significant difference between the water contents/fat-free weight of these two groups with contrasting intestinal fills.

Mice clipped of their fur had a higher water content than unclipped mice. Since the difference averaged 1.5 per cent of body weight for both normal and restricted mice, it was assumed that variation of fur density was not an important variable.

Measurements on the blood.—Tail-blood samples were obtained from lightly anesthetized mice. One sample of blood, for analysis of water content, was allowed to flow from the cut tail onto a tared slide. The blood was retained within a ring of vaseline and was immediately sealed off from the air by a tared cover slip. After the wet weight of the blood was determined, the coverslip was removed, and the slip and slide were dried several days in a calcium chloride desiccator and then reweighed. Wire hooks were attached to the coverslips so they could be hung up for drying and weighing.

A second sample, for measurement of blood specific gravity, was drawn into the stem of a red pipette. Pipettes used for this purpose were previously "heparinized" by rinsing with a 0.1 per cent solution of sodium heparinate and drying in a vacuum. Specific gravity of drops of this blood was measured in a bromobenzene-kerosene specific gradient tube, as described by Ponder (1943). The position of a drop in the gradient was read after 3½ minutes, rather than after one minute as by Ponder. Three and a half minutes was about one minute longer than necessary for a drop of blood to reach a nearly steady position. The drop would then very slowly sink from this nearly steady position, as blood lipids dissolved into the solvents of the gradient.

A third sample was drawn into a 2¾-inch long capillary coagulation tube. Tubes were checked for uniformity of internal diameter and "heparinized" before use. After a tube was ⅝ full, its ends were sealed with melted rosin-beeswax, and the tube was then centrifuged for 45 minutes at 2000–2100 rpm in a clinical centrifuge. Following centrifugation the lengths of the plasma, white cell and red cell components were measured to the nearest 0.1 mm.

RESULTS AND DISCUSSION

Weight changes.—Figure 2 shows the body weight changes during different levels of water intake. The plotted values are average weights for the individuals in each particular group. The range of individual values is relatively large, and averaging obscures certain weight relationships, but the average values indicate the trends of change.

In the left half of Fig. 2, weights are plotted for each of the three age groups. All age groups received the same treatment. The mice lost weight the first few days after being placed in the individual cylindrical cages, presumably while learning to eat from the food hoppers. But this loss was quickly recovered and the mice continued to grow as expected, averaging about 0.1 gm. increase per day between April 1 and April 22.

On April 22 the drinking water allotment was reduced to an average of 5.18 ml./mouse/day (49.7 per cent of the amount the mice had been drinking *ad libitum*). This restriction caused an immediate sharp loss of weight in the first day, but in following days the daily loss was gradually reduced until body weight was stabilized. A few mice that were continued on this level of intake recovered all lost weight (data not plotted). Further restriction on April 29 to 4.24 ml. or 40.7 per cent of *ad libitum* intake had no effect on the body weight of the older mice and only a small effect on the youngest mice. A third restriction to 3.38 ml. or 32.4 per cent of *ad libitum* also had little or no effect. These levels of restriction are considered "moderate restriction" since they did not prevent stabilization of weight loss in a short time, or recovery of lost weight.

The level at which stabilization of weight occurred seems to depend upon the initial weight of the mice. There is some indication that young mice (having low initial weights) require more time to stabilize their weight.

The data plotted in the right half of Fig. 2 are for three groups of mice of mixed ages that each received a different treatment, as follows:

1. Mice adjusted to an intake of 32.4 per cent of *ad libitum* were extremely restricted to 1.75 ml./day or 16.8 per cent of *ad libitum*. This resulted in a moderately sharp initial rate

of loss that gradually tapered off to zero after about ten days. As soon as weight was stabilized, the water supply was further restricted to 1.0 ml./day or 9.6 per cent of *ad libitum*. This caused a persistent, moderately sharp loss of weight that was fatal in about eight days. Mice of the 1955 experiments (data not plotted) were able to stabilize their body weight on 1.0 ml./day and had to be reduced to 0.75 ml./day or 7.2 per cent of *ad libitum* in order to cause a fatal weight loss.

2. Mice adjusted to an intake of 32.4 per cent of *ad libitum* quickly gained weight when returned to an *ad libitum* intake. In two days these mice recovered almost exactly their weight of April 22 before restriction began, and then continued to grow.

3. Complete deprivation of drinking water resulted in a very sharp loss of weight that was fatal in three to eight days. The data of Fig. 2 are adjusted so that all mice "died" on the average day of death. The initial rate of weight loss was greater for the heavier animals that had previously been drinking *ad libitum* (4.5 gm. lost during the first day of deprivation) than for the lighter animals that had previously been on a moderately restricted intake (2.0 gm. lost during first day). However, there is no difference between the rates of loss of the two groups if they are compared in the same weight range. Adjustment to restricted intake does not enable mice to survive deprivation any better than "unconditioned" mice.

The decline in daily weight loss with time (4.45, 2.91, 2.33, 1.90, 1.80 and 1.20 gm. in successive days) is apparently referable to the progressively declining body weight, rather than to a physiological conservation mechanism that becomes more effective with time.

Weight loss as related to initial weight.—The amount of weight lost following restriction of water intake was largely determined by the initial weight of the individual animal, i.e., its weight on *ad libitum* intake prior to restriction of intake.

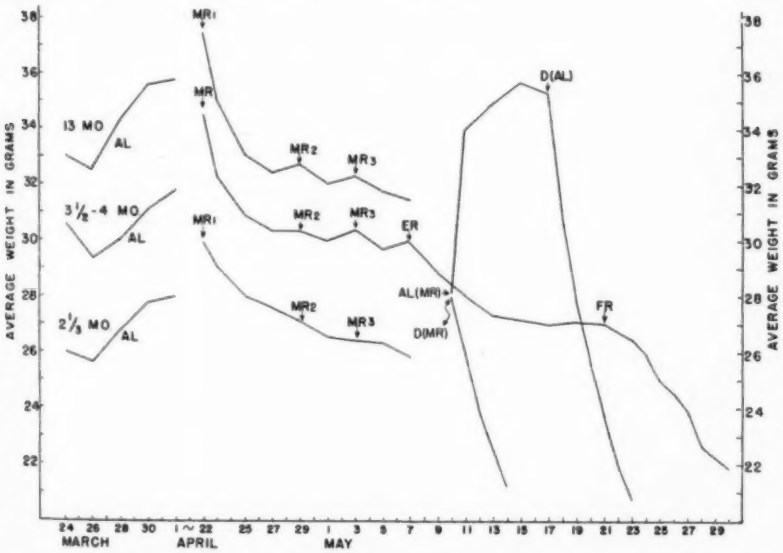

FIG. 2.—Weight changes of mice on different water regimens. AL—*ad libitum* intake, MR—moderate restriction, MR1—49.7% *ad libitum*, MR2—40.7% *ad libitum*, MR3—32.4% *ad libitum*, ER—extreme restriction to 16.8% *ad libitum*, FR—fatal restriction to 9.6% *ad libitum*, AL(MR)—*ad libitum* after moderate restriction, D(AL)—deprivation after *ad libitum*, D(MR)—deprivation after moderate restriction.

The minimum weight attained following moderate restriction to 32.4 per cent of *ad libitum* showed a linear regression upon initial weight according to the formula, $Y = 10.540 + 0.551X$, with a correlation coefficient of 0.800 (Y = minimum weight, X = initial weight). Data for both sexes and all three age groups fitted this regression equally well. There was an over-all coefficient of variation of 8.3 per cent.

The minimum weight following extreme restriction to 16.8 per cent of *ad libitum* could be predicted reliably from the regression equation, $Y = 8.788 + 0.531X$, with $r = 0.834$ and $C = 7.4$ per cent. Variation of observed values from predicted values was twice as great for females as for males, but age had no apparent effect on the degree of variation.

The weight at which an animal died following fatal restriction or complete deprivation of drinking water was related to the initial weight according to the equation, $Y = 15.517 + 0.166X$, with $r = 0.612$ and $C = 7.4$ per cent. Variation of females from predicted values was 50 per cent greater than for males, but age had no apparent effect.

This relationship between weight loss and initial weight indicates the probable fallacy of comparing different groups in terms of the percentage of initial weight lost, a frequent method of expression in the literature.

Food intake.—Data for food intake and body weight are summarized in Table 1. All groups listed in this table have similar proportions of males and females of each age group. Differences between certain means were tested for significance by t-tests.

Moderate restriction of drinking caused a highly significant decrease in food intake ($p < 0.01$). Extreme restriction caused no further change. Extremely restricted mice maintained one gram of body weight on 0.167 gm. food per day, while normal mice ate 0.209 gm. food/day/gm. body wt. The lower food requirement of restricted mice is presumably due to: stoppage of growth, reduction of activity (French, 1956; and others), lowered metabolic rate (Chew, 1951), and greater efficiency of food utilization in the restricted mice (Quimby, 1948).

Food intake was still lower when drinking was fatally restricted. This lowering was not statistically significant, but it was physiologically significant in that it exceeded the "break-even" point at which weight balance could be maintained ($= 0.167$ gm./day/gm. body wt.). After the first day of fatal restriction, food intake remained constant at the lower level. There

TABLE 1.—*Summary of data for mice on different levels of water intake, 1954 experiments. Each value is the average for all mice in the group, ± one standard deviation*

Condition of water intake	No. mice	Body wt., gm.	Gm. food/gm. wt.	Ml. water/gm. wt.	Gm. food/ml. water
Ad libitum	40	31.72 ± 4.67	.209 ± .017	.330 ± .068	.652 ± .092
Moderate restriction to:					
49.7% *ad libitum*	32	31.50 ± 4.37	.165 ± .019	.165 ± .028	1.02 ± .165
40.7% *ad libitum*	23	30.70 ± 4.10	.174 ± .020	.137 ± .026	1.28 ± .021
32.4% *ad libitum*	32	29.69 ± 4.12	.172 ± .023	.111 ± .027	1.57 ± .304
Extreme restriction to					
16.8% *ad libitum*	16	27.83 ± 3.78	.167 ± .032	.0636 ± .014	2.79 ± .710
Fatal restriction to					
9.6% *ad libitum*	5	24.20 ± 1.72	.154 ± .028	.0414 ± .003	3.71 ± .670
Deprivation after moderate restriction	8	23.85 ± 2.72	.121 ± .038		
Deprivation after *ad libitum*	8	24.89 ± 2.72	.077 ± .038		
Ad libitum after moderate restriction	8	34.96 ± 3.55	.223 ± .037	.343 ± .053	.656 ± .141

was no progressive decrease in intake, and even on the last day of life only two of eight mice showed any marked decline in eating. Death resulted from a culmination of moderate negative weight balances on each of six to eight days.

When no drinking water was available food intake was significantly lower than during extreme restriction. However, as shown in Fig. 3, there was no abrupt stoppage of eating as observed for the white rat (Adolph, 1947). The deprived mice were subjected to moderate chronic starvation rather than abrupt severe starvation. After the first day of deprivation approximately half the mice showed a relatively consistent food intake through the day of death.

The deprived and fatally restricted mice made a definite effort to eat. They chewed up more Purina Chow than mice receiving more drinking water, but most of the fragmented chow was not swallowed and dropped into the spillage trays under the food hoppers. Inadequate drinking water apparently interfered with swallowing (probably because of insufficient saliva to lubricate the food), but not with the drive to eat.

It was observed that the extremely restricted mice drank their entire water ration as soon as it was available. Thus all of their eating for the next 24 hours was accomplished without any necessity for drinking alternating with eating (the normal sequence as shown by French, 1956). This suggests that in nature one relatively small drink (10 per cent or less of the "desired" amount) of dew in the early morning would be sufficient to get a mouse through

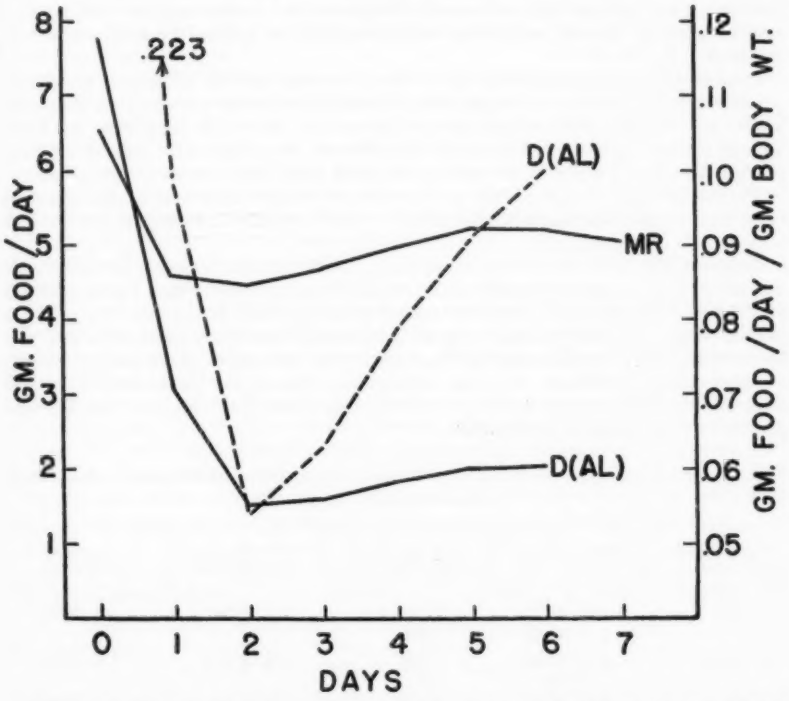

FIG. 3.—Food intake of mice on different water regimens. Solid line—intake as gm./day; dotted line—intake as gm. food/day/gm. body wt.

one to several days. The consistent inability to get one drink to supplement other water intakes might prove fatal.

The ability of white mice eating air-dry food to survive on approximately 10 per cent of their normal drinking water intake exceeds, percentagewise, the ability of some species of *Peromyscus* (Chew, 1951; Lindeborg, 1952), although *Peromyscus* survived on a somewhat smaller absolute quantity of water (0.4–0.8 ml./day). Both percentagewise and in terms of absolute volume, the ability of *Mus* to survive on limited water intake exceeds that of *Microtus* (Lindeborg, 1952).

Relationship between food intake and water intake.—The food/water ratios in Table 1 show that food intake is not closely tied to water intake. The ratio increases as drinking is reduced, with no indication of a sharp limit. However, at the level of fatal restriction the increase in the ratio failed to keep pace with the decrease in water intake, and body weight slowly decreased.

There is no support for the tentative explanations of Bing and Mendel (1931) that white mice drink in order to moisten the air-dry food they are eating and render it capable of ingestion, or that the amount of water required for lubrication approximately equals the weight of the dry food, i.e. food/water = 1.

While the weight of food eaten is not closely dependent on the volume of water drunk, there is an obvious relationship between the two, as shown in Fig. 3. A new, lower level of food intake was achieved on the first or second day of an altered water regimen, and total food eaten then remained relatively near the first-day value. As the weight of food eaten remained relatively constant, while body weight continued to decline, the food/weight ratio increased.

Food intake in relation to age and sex.—When water was available *ad libitum*, young mice ate more food per gram of body weight than older mice, and female mice ate more than males (Table 2). The differences among the age groups were statistically significant. However, age and sex seem to be important only as they influence the weight of the individual mice—young mice being lighter than old, and females being lighter than males of the same age.

The amount of food eaten per day per gram of body weight showed an inverse regression upon body weight according to the formula, $Y = 0.287 - 0.00246X$, which fits data for both sexes and all ages equally well.

Lighter weight mice can be expected to have a greater food requirement per unit weight because they have a greater growth energy requirement, and because their bodies contain a higher percentage of active tissues in contrast to metabolically less active adipose tissue. Lighter weight mice also showed a higher water intake than heavy mice. This may also be accounted for on the basis of energy requirements, i.e., more water turnover associated with a higher energy expenditure. Since the difference in water intake between young and old mice was proportionately greater than the food intake difference, young mice ate less food per unit of water intake than older mice.

TABLE 2.—*Food and water intakes of mice of different ages on ad libitum water intake. Each value is a group average*

Age in months	Body wt., gm.	Gm. food/day/ gm. body wt.	Ml. water/day/ gm. body wt.	Gm. food/ ml. water
13	♂ ♂ 36.92	0.198	♂ ♀ 0.287	♂ ♀ 0.70
	♀ ♀ 33.52	0.198		
3½–4	♂ ♂ 32.44	0.209	♂ ♀ 0.336	♂ ♀ 0.64
	♀ ♀ 28.15	0.212		
2⅓	♂ ♂ 29.70	0.220	♂ ♀ 0.407	♂ ♀ 0.57
	♀ ♀ 24.75	0.240		

Differences in food intake among the three age groups were also present at levels of moderate and extreme restriction, but were not statistically significant.

Weight changes during transition periods.—It is interesting to consider the transition points in the experiments at which sharp weight changes occurred. The sharp weight loss during the first day of moderate restriction of drinking seems to be largely due to a reduction in food intake during this day. For the three age groups (13, 3½–4, and 2⅓ months) the average weight losses during this day were 2.5, 2.2 and 0.9 gm., respectively, while food intakes were 2.3, 2.0 and 1.7 gm. less than the previous *ad libitum* intake. There is no indication in this comparison that the sharp loss of weight was due to a loss of "surplus" water from the tissues before water conservation mechanisms were activated, as seems to occur in humans (Ladell, 1957). Data on body water contents (Table 5) show that there was a dehydration of the body during the period of moderate restriction, but apparently this was not a sudden dehydration.

The mice that were shifted abruptly from unlimited to no drinking water lost an average of 4.46 gm. the first day. This loss was due partly to a solids deficit of 3.7 gm. of food, and partly to a loss of water that could not be replaced.

Mice shifted from moderately restricted water intake to no water lost 2.0 gm. the first day. Since food intake was unchanged (down only 0.1 gm.) this loss was apparently entirely due to a water deficit.

When water was provided *ad libitum* to mice previously on restricted intakes, there was a sharp weight gain averaging 5.85 gm. the first day. Food intake this day exceeded the previous day by 3.9 gm. and water intake was 13.3 ml. greater. Thus something less than 3.9 gm. of the weight gain was due to an increase in solids and something more than 1.95 gm. was due to water added to the tissues. It is possible that there was some "flooding" of the tissues with water due to an imperfect diuresis response, as found for dogs by Dicker (1949).

Behavior.—Interesting behavior changes occurred in the mice that were restricted to 16 per cent or less of their desired amount of drinking water. These mice became quite aggressive, occasionally escaped from cages previously considered escape proof, immediately ran from the cage area when free, and were quite alert and agile in avoiding recapture. These same mice were quite placid when they were eating and drinking *ad libitum*; they made no effort to escape when left free on a table top.

This suggests that the wildness of wild species and feral individuals of domestic breeds may be at least partly due to a chronic insufficiency of water and food.

Lipid content.—Table 3 summarizes the data on total body lipid content of mice on different drinking water regimens. The data were not analyzed statistically because of the large variability within groups due to age and sex differences. Older mice and female mice had higher lipid contents.

The average values for different groups indicate that there was no significant change in lipid content until the mice were fatally restricted. Although moderately and extremely restricted mice lost weight, they apparently did not utilize fat out of proportion to other body solids. They stabilized their weight at a lower level, with unchanged fat composition. However, when water was fatally reduced food intake dropped below the "break even" point, body fat was utilized to make up the energy deficit, and body lipid content dropped to a very low level. At the time of death, lipid content was approximately one per cent of the total weight, but this was probably very largely lipid associated with the structure of protoplasm, rather than simple fat in storage in adipose tissue. At autopsy, no visible fat deposits were present, and these energy stores were probably completely exhausted. Starvation must have been an important causative factor in death of the mice.

Analysis of specific organs from a different group of mice (Table 4) gave the same result. There was no significant change in the fat content of gastrocnemius muscle or liver samples until the mice were fatally restricted or deprived of water. The liver samples showed less of a reduction in lipid content than muscle.

TABLE 3.—*Body lipid contents of mice on different water regimens. Each value is a group average; range in parentheses*

Water intake condition		Lipid content, % total wt.	Lipid content, % dry wt.
Ad libitum	♂♂	5.8 (3.4–10.1)	18.8 (11.9–33.3)
	♀♀	10.0 (5.7–14.7)	30.1 (19.0–39.9)
Moderate restriction to 32.4% of *ad libitum*	♂♂	4.4 (3.6– 5.1)	13.8 (12.0–14.9)
	♀♀	6.5 (3.4–11.7)	19.4 (10.8–32.3)
Extreme restriction	♀♀	6.3 (2.4–11.2)	18.7 (7.7–32.9)
Fatal restriction	♂♂	1.4 (1.0– 1.8)	4.4 (3.2– 5.6)
Total deprivation after moderate restriction	♂♂	1.2 (0.9– 1.5)	3.6 (2.6– 4.3)
	♀♀	1.4 (1.3– 1.5)	4.7 (4.1– 5.1)
Total deprivation after *ad libitum*	♂♂	1.2 (1.1– 1.2)	3.8 (3.6– 3.9)
	♀♀	1.4 (1.1– 1.7)	4.6 (3.5– 6.0)

Body water content.—If body water content is expressed in terms of total body weight, there are no significant differences among mice kept on different water regimens (Table 5). The mice that were dying because of lack of water had the same water content as normal mice. This agrees with a previous observation on *Peromyscus leucopus* (Chew, 1951), and would indicate that the mice died without undergoing any actual dehydration, except that the variable of fat content is not taken into account.

Table 3 shows that the bodies of the mice involved always contained a certain amount of lipid—a relatively large amount in mice with sufficient drinking water to survive. Since no water is associated with stored fat, the fat acts as a dilutant of body water. Fat contributes to the total weight, but not to the space available for water distribution. Therefore, it is erroneous to express water content in terms of total body weight, as has been frequently done in the literature.

If water content is expressed as a percentage of the fat-free body weight (Table 5), it is seen that the water content decreased even when the mice were moderately restricted. The decrease is, statistically, highly significant ($p < 0.01$). Water content was further significantly decreased when the mice were fatally restricted.

Therefore, there is an actual dehydration of the body when drinking is restricted—a loss of water in excess of its normal ratio to solids. This dehydration may have been an important factor in the death of the mice dying of restriction. No comparative data are available to

TABLE 4.—*Lipid and water contents of gastrocnemius muscle and liver samples of mice on different water intakes. Each value is an average for four mice*

Water regimen	Lipid content as % dry wt.		Water content % fat-free wt.	
	Muscle	Liver	Muscle	Liver
Ad libitum	27.2	13.4	75.9	71.5
Extreme restriction	26.9	10.2	74.6	73.3
Fatal restriction	3.03	8.33	73.8	72.1
Deprivation	4.71	7.48	72.6	70.9

TABLE 5.—*Total body water content of mice on different water regimens. Group average ± one standard deviation*

Conditions of water intake	Water content, % total weight	Water content, % fat-free wt.
Ad libitum	68.49 ± 2.94	74.59 ± 0.85
Moderate restriction to 32.4% of *ad libitum*	68.20 ± 2.32	71.55 ± 1.18
Extreme restriction	66.89 ± 1.83	71.43 ± 2.17
Fatal restriction	67.79 ± 0.34	68.78 ± 0.28
Total deprivation after moderate restriction	68.50 ± 1.94	69.62 ± 2.14
Total deprivation after *ad libitum*	68.74 ± 2.01	69.65 ± 2.14

indicate if the degree of dehydration of these mice is less or greater than that occurring in other species. It is not possible to convert literature reports of fatal water loss as a percentage of initial weight, or fatal water deficit of loss over intake as a percentage of initial weight, into actual water content of the body at the time of death.

Dehydration was not shared equally by different parts of the body. Liver samples showed no significant change on any level of restriction, while gastrocnemius muscle was significantly dehydrated during fatal restriction (Table 4). De Boer (1946) found a dehydration of muscle from 79.2 to 78.1 per cent of fat-free weight in dogs deprived of food and water for 6–7 days. Skin water content simultaneously dropped from 77.3 to 72.7 per cent, and was still 72.3 per cent 4–5 days after the dogs were returned to *ad libitum* drinking. Dicker (1949) also found significant muscle dehydration in dogs deprived of water. Skelton (1927) found marked dehydration of the liver in cats that were acutely dehydrated. Flemister (1941) has shown that the skin is the most flexible water reservoir in the rabbit.

Blood water content.—Table 6 summarizes the data on blood analyses for the 1955 experiments. The water content of the whole blood was significantly reduced in the fatally restricted and deprived mice. Calculations indicate that this water-content change was restricted to the blood cells. The distribution of water between cells and plasma was calculated on the basis of Ponder's (1943) values for estimation of plasma protein from plasma density, and on the assumption of 0.009 gm. of nonprotein solids per ml. of plasma. The calculated values are:

Water regimen	*Plasma water content, %*	*Blood cell water content, %*
Ad libitum	93.0	61.5
Extreme restriction	92.5	62.9
Fatal restriction	92.5	55.9
Deprivation	92.5	59.5

These values indicate that the plasma is stable while the blood cells are being dehydrated. This agrees with the observations of Dicker (1949) who found a normal plasma water content in dogs deprived of water, but not food, for six days. Elkinton and Taffel (1942) found a serum water reduction, from 93.1 to 90.7, in dogs deprived of water and food for 11–20 days.

Plasma specific gravity.—An analysis of variance of the data on plasma specific gravity indicates that the restriction of drinking caused a significant change in specific gravity. The difference between treated groups collectively and the control group (*ad libitum* intake) was significant ($p < 0.05$). However, none of the individual group means was significantly different from the control mean. The deprived group mean came closest to significance

($p = 0.06$). These data also indicate a stability of the plasma. Brokaw (1949) found an increase in plasma solids of 1.15 per cent in rats deprived of water and food.

The value of 1.025 for the plasma specific gravity of normal mice is within the range of values reported for female white rats, 1.018–1.027 (Albritton, 1952). There are no comparative values for mice.

Whole blood specific gravity.—Whole blood specific gravity was significantly altered by restriction of drinking. The means for the fatally restricted and deprived groups are significantly different from the *ad libitum* group ($p < 0.02$). The mean value for normal mice, 1.061, compares well with values reported for mice, 1.057 (range 1.052–1.062), by Albritton (1952).

Hematocrit.—The hematocrit data are quite variable, and there is no significant difference between the control group and the treated groups. However, there is an important difference among the treated groups. Abrupt deprivation resulted in an increase in the hematocrit value, while chronic restriction, finally to the fatal point, resulted in a drop in the red cell volume. The means for the two groups are significantly different ($p < 0.03$). This suggests that chronic restriction, by causing starvation, interferes with the ability of the bone marrow to form erythrocytes, and thus reduces the hematocrit. Abrupt deprivation causes a mobilization of total blood volume from the spleen, and this spleen reserve, with its higher cell content, increases the hematocrit.

The hematocrit of the deprived mice increased 10.0 per cent. This compares well with the 7–14.5 per cent increase found by Brokaw (1949) for white rats deprived of water for 5–7 days, but does not approach the 23.5–27.5 per cent increase she found for rats dying of deprivation.

TABLE 6.—*Data for blood samples drawn on May 16–20 after 31–35 days on different water intakes. Average values ± one standard deviation*

Water regimen	Water content, % total wt.	Sp. gravity of plasma	Sp. gravity of whole blood	Hematocrit
Ad libitum	76.6 ± 0.88	1.025 ± .0014	1.061 ± .0033	48.6 ± 3.02
Extreme restriction	76.1 ± 0.85	1.027 ± .0008	1.065 ± .0044	51.3 ± 2.44
Fatal restriction	75.1 ± 3.66	1.026 ± .0021	1.066 ± .0044	44.8 ± 6.28
Deprivation after extreme restriction	74.9 ± 1.18	1.028 ± .0008	1.069 ± .0009	52.5 ± 2.33

SUMMARY AND CONCLUSIONS

White mice were subjected to chronic restriction of drinking water intake ranging in intensity from half of *ad libitum* intake to no water. Body weight, food intake, blood composition, and body water and lipid contents were measured.

White mice lose weight when their drinking is restricted, but are able to stabilize their weight at a lower level and survive on as little as 1.0 ml./day (9.6 per cent of *ad libitum*). "Conditioning" by experience with restriction does not enable mice to tolerate lack of water any better than "unconditioned" mice.

Even moderate restriction of drinking, to half of *ad libitum*, reduces food intake to a point where weight balance can be barely achieved. The "break-even" intake is about 0.167 gm. air-dry Purina Chow/day/gm. body wt., as com-

pared to 0.209 gm. normal intake. This break-even intake can be maintained until drinking is reduced to 10 per cent of normal.

Food intake reaches its new level during the first or second day of a new water regimen and then remains relatively constant at that level. Mice deprived of drinking water continue to eat, as much as 0.12 gm./day/gm. body wt.

Restricted mice do not draw upon their fat stores until food intake drops below 0.167 gm./day/gm. wt. Total body lipid content at death following fatal restriction is 3.8–4.6 per cent of dry weight, compared to 18.8–30.1 per cent in normal mice.

Body water content, expressed as water/fat-free wt., is lower for restricted mice than for normal mice—indicating a true dehydration of the body, a loss of water in excess of its normal ratio to nonfat solids. Dehydration is significant in moderately restricted mice, is still greater in fatally restricted individuals, and could be an important factor in causing death.

Blood water content is reduced only during fatal restriction, and the reduction is apparently limited to the blood cells. Plasma water content and specific gravity remain relatively stable.

The hematocrit is reduced by chronic, finally fatal, restriction. This reduction is possibly due to a nutritional failure in the bone marrow, and, along with depletion of the body lipids, indicates the importance of starvation as a cause of death following restriction of drinking.

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OBSERVATIONS ON THE ABUNDANCE OF KOREAN MICE

BY DAVID E. DAVIS

The description by Youngman (1956) of populations of mice in abandoned areas in Korea suggests that some previously collected data are worthy of comparison. This report describes some observations on the relative abundance of mice on the hills in which United Nations troops were camped in October and November of 1953. The captures were part of a study of haemorrhagic fever sponsored by the Armed Forces Epidemiological Board.

The area had been more or less occupied by troops for several years and since July, 1953, a number of camps had been permanently located in the area. Before the Korean War the area had been intensively cultivated and several thousand people lived in the valley.

The local inhabitants abandoned the area during hostilities and their small rice and grain fields developed a prolific growth of weeds. The following plants are abundant. *Rosa multiflora* and *Quercus mongolica* provide excellent shelter and food. Several shrubs (*Spirea salicifolia, Rhamnus davurica*) are also important. The legumes (*Lespedeza stipulacea* and *Glycine soja*) fruit prolifically. Many grasses (*Echinochloa crusgalli, Setaria faberii, Themeda japponica, Phragmites communis* and *Miscanthus sacchariflorus*) are widely distributed, as well as some sedges. The above list of plants indicates that a superb habitat in terms of food and shelter has developed in the abandoned areas.

Methods.—Trap lines were placed at the base (I), on the side (II), and near the top (III) of a hill. Each line consisted of 20 stations placed at 50-foot intervals and having three traps. The lines were parallel and about 100 feet apart.

The traps were "museum specials," baited with plain peanut butter. The traps were visited each morning for three days, and then picked up and set in a new location. A total of seven locations was set but two areas were molested by troop activities, which made the results useless. The dead mammals were brought to camp where ectoparasites and data were collected.

The population was estimated by the procedure developed by Zippin (1956) which is an elaboration of the "catch-effort" method of DeLury.

Results.—Table 1 gives the results and the values calculated by Zippin's method for *Apodemus agrarius* (the long-tailed field mouse) which is by far the most abundant species. The results show no difference in numbers captured at the base of the hill (lines I) and near the top (lines III). However, the lines on the sides (lines II) produced significantly more (P .001) mice than the other lines.

The density of the mouse population cannot be determined because the home range, and hence the area from which the individuals are drawn, is unknown. However, we may make some guesses about the extent of home range to get some idea of the density. Let us first assume simply that the traps draw mice from a distance of 50 feet around each line (assumption A). This produces a rectangle around each line, 100 × 1050 feet, which is a little less than 2.5 acres. Since there were five locations, the total area for each type of line is about 12.5 acres. Thus the densities are about 30, 50 and 30 mice per acre (Table 1).

We can make perhaps a more realistic assumption (B), namely, that the mice on the border lines (I and III) and at the ends are drawn from 100 feet. Lines I and III will thus be rectangles 150 × 1150 feet, or about 4 acres. Line II will be 100 × 1150 feet, or about 2.5 acres. Thus each line II is about 2.5 acres and each line I and III is about 4 acres or, for the five areas, 20, 12.5 and 20 acres. The densities would be about 20, 50 and 20 mice per acre (Table 1).

These densities may be compared with those that normally occur for *Peromyscus bairdi* which is ecologically the most comparable species in the United

TABLE 1.—*Calculations of numbers of* Apodemus agrarius *at three levels*

Location of lines	I	II	III
Mice captured on first day	80	73	90
Mice captured on second day	62	65	74
Mice captured on third day	50	57	50
Total captured (in 5 areas)	192	195	214
R (see Zippin, 1956)	.844	.918	.813
P (probability of capture)	.21	.12	.57
N (population exposed)	376	609	375
Standard error (mice)	81	239	54
Densities per acre:			
Assumption A	30	50	30
Assumption B	20	50	20

States. Blair (1948: 417) gives data in terms of populations per acre for 5 years. The numbers vary from essentially zero to 9.2, demonstrating the usual variation that may occur in one place.

Another set of data is useful to gain perspective on these estimates for Korean mice. The area around Thomasville, Georgia, in 1954 had the highest mouse populations in 24 years, according to E. V. Komarek. Dr. R. Z. Brown generously provided data from a field that had been cultivated two years ago. The estimate was 52 mice per acre (*Mus musculus* and *Peromyscus polionotus*). Ecologically this field is very similar to the Korean hillsides. One cannot compare such data in detail, but may feel confident that the density in Korea was "unusually high."

Other species were captured in small numbers. Those taken on all lines in seven areas included the following: *Apodemus agrarius*, 734; *Micromys minutus*, 16; *Mus musculus*, 28; *Clethrionomys rufocanus*, 12; *Microtus mandarinus*, 3; *Cricetulus triton*, 9; and *Crocidura lasiura*, 39. The totals were too small to merit calculation of population. No difference in abundance according to location of line was apparent. *Crocidura* was probably under-represented, because neither bait nor set was well suited to a shrew. *Cricetulus* was probably also under-represented, because many individuals were too large for the trap used. *Microtus* was clearly scarce in that habitat in that season.

Discussion.—These population estimates are obviously about 10 times as high as the densities of 2–4 mice per acre calculated by Youngman (1956: 8). The difference appears to be real and not due to sampling vagaries.

Actually, Youngman's calculations are high because they are cumulative and not instantaneous. He counts all the animals in the area during a period of 5–8 weeks, thus including replacements for those that die. The instantaneous density is the number at a particular time. An estimate of the instantaneous density in a stationary population can be obtained from the formula $N = P + qP$, where N is number caught or observed, P is instantaneous population, and q is probability of dying during the time period. If we assume that $q = 0.2$ for five weeks (which is a reasonable guess for mice of that size) then Youngman's densities are about 20 per cent higher than the actual density.

Youngman's densities also appear to be high because he used a home range based on only four captures per mouse. While this number was justified when used by Blair (1951), the partial data presented by Youngman (1956: 9) indicate that the apparent home range was increasing with increasing numbers of captures beyond four. Without adequate data it is impossible to say what the error amounts to, but the home range was too small.

The two studies were conducted about five miles apart, but in different valleys. The vegetation seemed very similar in both areas. One study was made in the fall of 1953, the other in the spring and early summer of 1954. Several possibilities may explain the great difference in densities. (1) Technical. It may be that the traps used by Youngman were unsuitable. He made no check with conventional snap traps. (2) A real seasonal decline occurs during the

winter. This possibility seems remote because declines of this magnitude are rarely recorded for seasonal changes. (3) A "crash" occurred in the population. Declines of this magnitude have often been recorded for microtine rodents and occasionally for murine rodents, such as *Mus musculus*, which is fairly closely related to *Apodemus*. Unfortunately, current information cannot determine which, if any, of these possibilities actually is the explanation.

Summary.—Estimates of the population of the Korean long-tailed field mouse in the fall of 1953 near the 38th parallel showed that higher populations occurred on the hillsides than at the base or top of the hills. The densities were very high, being perhaps 20–50 mice per acre.

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HOME RANGES AND POPULATIONS OF SMALL MAMMALS IN CENTRAL KOREA

BY J. KNOX JONES, JR. AND ALBERT A. BARBER

The evolutionary and genetic importance of the dynamics of natural populations of mammals has been reviewed by Blair (1953). Knowledge of population dynamics among mammals that are known or suspected reservoirs of disease is important because some aspects of transmission and spread of diseases and their control depend on distribution, both geographic and ecologic, populations, movements and reproduction in the reservoir species involved.

Several species of indigenous murid and cricetid rodents have been studied as potential reservoirs of hemorrhagic fever in Korea by the Field Unit of the Commission on Hemorrhagic Fever (Traub *et al.*, 1954). As a continuation and

integral part of these studies, distributional and general ecological information has been gathered on various small mammals and their populations in Korea (see Youngman, 1956). The present paper presents the results of studies made on a 12.86-acre plot in the Central National Forest, a natural mixed forest at least 450 years old, approximately 15 miles northeast of Seoul, in the late summer and autumn of 1954 when the authors were assigned to the Field Unit of the Commission on Hemorrhagic Fever of the Armed Forces Epidemiological Board at the 11th Evacuation Hospital near Seoul.

ECOLOGICAL ASSOCIATION

The area studied was on a southwest-facing hillside that rose from the valley of a small tributary of the Wangsuk River. Several small streams trickled down through the plot, one on the southeastern side and another near the center. Slope of the hill was, in general, gradual except on the southeastern edge where the slope rose more abruptly. Granite outcroppings were common, especially along the streams. The soil was a rich, dark brown, covered almost everywhere by several inches of litter. The nearest established urban area was the town of Pup'yong-ni, approximately 2 miles to the southeast. The approximate geographic coordinates of the study plot were 37° 45′ N, 127° 10′ E.

The study area was in a deciduous association of the mixed forest, an association that was common to most of the lower slopes in the Central National Forest. On most parts of the plot there was a dense canopy (Plate I, Top). A few partly open areas were present, principally along the bottom border. Ground cover was more luxuriant in these relatively open spaces than on the forest floor (Plate I, Bottom). Some of the more common trees on the plot were: oaks, *Quercus acutissima*, *Q. mongolica* and *Q. serrata;* maple, *Acer pseudo-sieboldianum*; silver bells, *Styrax obassia* and *S. japonica*; sumac, *Rhus javanica*; ash, *Fraxinus rhyncophylla*; the kalopanax, *Kalopanax pictus*; hornbeam, *Carpinus* sp.; the maackia, *Maackia ?floribunda*; wild cherry, *Prunus* sp.; pine, *Pinus koraiensis*. Ferns, *Athyrium* sp., *Botrychium* sp., and *Microlepia* sp., grew along the little streams and on the forest floor. Shrubs were common on the study area, especially in more open ground. Species identified were: lespedeza, *Lespedeza bicolor*; bittersweet, *Celastrus flagellaris*; black haw, *Viburnum erosum*; spindle tree, *Evonymus alatus*; mock orange, *Philadelphus* sp., privet, *Ligustrum ibota*; bladder fruit, *Staphylea bumalda*; egg-yolk shrub, *Symplocos paniculata*; and also *Alangium platanifolium*; *Ampelopsis brevipedunculata*; *Stephanandra incisa*; *Lindera obtusiloba*; *Securinega suffruticosa*; *Fagara manchurica*; *Photinia villosa*. Herbs that were identified from the study area are arranged alphabetically as follows: *Amphicarpaea trisperma*; *Aster* sp.; *Atractylodes* sp.; *Cacalia* sp.; *Carex mollicula*; *C. nanella*; *C. siderosticta*; *Diarrhena fauriei*; *Disporum smilacinum*; *Isodon* sp.; *Lysimachia barystachys*; *Melampyrum roseum*; *Muhlenbergia* sp.; *Paraixeris denticulata*; *Phryma leptostachya*; *Potentilla fragarioides*; *Smilax nipponica*; *Stipa pekinensis*; *Spodiopogon sibiricus*; *Synurus* sp.; *Vicia bifolia*; *V. venosa*.

PLATE I

TOP: Typical view of the study area taken near the center of the plot. BOTTOM: One of the more open places on the study area. Note the more luxuriant ground cover as opposed to that in photograph above. Both photographs taken by senior author on 9 October, 1954.

Weather data available for the period 31 July to 27 August 1954 from Seoul City Airport on the Han River approximately 20 miles southwest of the study area are here recorded and correspond with weather notes taken by us during the investigation. The average daily maximum temperature was 88.4° F. (71–95°) and the average minimum, 74.0° (65–78°). The average daily relative humidity was 80.1 per cent (69–92). Precipitation was recorded on 16 of the 28 days covered in the weather data. Two inches of rainfall on 21 August was the most precipitation in any one day.

Predatory snakes taken on the study area were *Ancistrodon halys, Elaphe schrenckii* and *Dinodon rufozonata*. Four specimens of the latter were caught in live traps but none was in a trap with a small mammal. Autopsies revealed no mammals in any of the snakes. An owl, possibly *Asio flammeus*, was seen once on the study area. Carnivorous mammals known to occur in the Central National Forest were the fox, *Vulpes vulpes*, and two weasels, *Mustela sibirica* and *Mustela nivalis*. Only the latter was actually observed on the plot.

Other small terrestrial mammals present but not represented in our captures were the squirrel, *Sciurus vulgaris*, and the hare, *Lepus coreanus*. Both species were uncommon. Tunnels of the mole, *Talpa wogura*, were abundant in the moist soils, especially along the lower border of the plot.

METHODS

Field techniques employed were essentially those outlined by Blair (1941*a*). Our aim was to live-trap small mammals on the study area and mark and release them where captured in order to learn something of their populations and movements. Trapping was begun on 30 July on an 11.25-acre plot (700 × 700 feet) that was staked in a grid pattern with stakes 50 feet apart. Lines that ran up the hill were numbered from one to fifteen and traps were set at stakes along the odd-numbered lines. A line of traps was moved nightly along the seven even-numbered lines. Thus, of 135 traps in operation, 120 were stationary at stakes every 50 feet in lines 100 feet apart with a line of 15 traps that was moved along even-numbered lines so as to trap each station once every seven days. A shortage of traps prevented our trapping at all stations at the same time. The plot was enlarged to 12.86 acres on 6 August with 100 feet (two lines) added to the northwest side of the area. Traps were placed along the outermost of the two new lines and the inner one was incorporated into the schedule of the "roving" line. On 21 August the entire plot was rearranged so that two outside lines on opposite ends of the plot, plus all even-numbered lines in the center, were trapped for the last week. Trapping was ended on 27 August. It was originally planned to live-trap the plot again for a month in the autumn but circumstances at that time permitted only a three-day trap-off period (22–24 October) with Museum Special traps. At that time traps were set at all 255 stations for three consecutive days and nights. A short summary of the results of the October trap-off period has been appended to each species account.

Live traps available to us were of wooden construction and similar to those

described by Blair (1941*b*) but with one notable exception. They lacked a latch to prevent multiple captures and escapes. A previous user had bored small holes in the sides of the traps behind the level of the closed door so that a piece of wire could be inserted to lock the traps shut. Mice frequently enlarged these holes and before the end of trapping operations a number of traps had to be repaired with wire mesh. Traps were left set throughout the course of the study so as to catch both diurnal and nocturnal mammals. Traps were checked twice daily—early in the morning and in the late afternoon or early evening. When the same animal was caught in a trap on two successive nights, that trap was usually turned over and left unset on the third evening. During the excessively wet weather of the latter part of the summer, whole kernels of corn were used exclusively as bait because other baits available to us were washed away. Rolled oats were used as bait for snap traps during the October trap-off period.

Small mammals were marked on the right ear with numbered metal tags and released at the point of capture. These tags proved adequate for the month-long August study but by October many tags had been lost. Eight of 21 adult *Apodemus agrarius coreae* taken in the October trap-off period had deeply notched ears, almost certainly the result of the loss of tags. Two mice were known to have lost tags in the latter stages of the August live-trap period.

Korean civilians were informed about the study area by local police and forestry officials and, in general, were fairly cooperative. However, although we were on the plot a good deal of the time during daylight hours, traps and stakes were occasionally taken. We have no way of knowing whether traps taken contained animals though we suspected that some chipmunks were removed as they were of local commercial value as pets.

Animals were released from traps into transparent plastic bags for handling. These proved, in our experience, superior to cloth bags (see also Barbehenn, 1954). Daily records, in addition to trapping information, included data on breeding and molt, direction traveled from stake after release and location of hole if the animal could be traced to one. Those animals that had completed the molt from juvenal pelage were considered, for our purposes, to be adults. Those animals that were still in juvenal pelage or molting from that pelage were classed as juveniles.

A method of estimating home ranges suggested by Blair (1940 and elsewhere) is here employed. To eliminate most of the fractional home ranges, only animals that had been caught at least 150 feet within the borders of the plot are included in home-range calculations. The home ranges of some of these individuals may well have extended beyond the borders of the study area but to exclude them would have excluded some of the largest home ranges. In statistical treatment of size of home range, standard error of the mean has been used.

Blair (1951 and elsewhere) has separated residents from transients at four captures, whereas we, influenced by several considerations, have used three captures to separate these categories. We noticed, for instance, that mice

trapped only twice were usually captured on consecutive days or at least on dates close together. Most of the mice taken three times, like those taken four or more times, were captured over a relatively long period.

To compute numbers of mice per acre an "effectively trapped" area was approximated. Following Blair (1941*a*), there was added to the borders of the plot "half the width of the average home range," which we have taken to be equivalent to the radius of such average home range considered as a circle.

ACCOUNTS OF SPECIES

Apodemus agrarius coreae Thomas

Striped field mice were abundant on the study area as they were in many parts of central Korea. Altogether, 123 animals were captured a total of 857 times in the August study period. Individuals were distributed over the entire plot but the greatest concentrations of these mice were in the less densely wooded parts of the study area where ground cover was more luxuriant.

New mice were tagged on all but two of the 28 trapping days. Twenty-one were tagged in the last week of trapping operations, an average of three per day. Striped field mice were chiefly active during crepuscular and nocturnal periods but we noted also considerable diurnal activity. Ninety-seven of the 857 captures of this species (11.3 per cent) were recorded in the daylight hours. Occasionally we watched these mice forage in the daytime, usually in mid-morning or late in the afternoon. On several occasions we watched mice enter traps.

Home range.—The trap-revealed home ranges of 13 adult males, captured an average of 18.1 (7 to 37) times, averaged 1.70 ± .25 acres. The largest home range was 3.50 acres and the smallest, 0.63 acres (Table 1). The average greatest-distance between captures of these males in any 24-hour period was 72 per cent of the average greatest-distance between captures throughout the entire period of study.

Burt (1943), Stickel (1954) and others have pointed out the necessity of disregarding, for the purposes of home-range estimation, movements of mice outside the boundaries of their established home ranges. These may be forays of an exploratory nature or wanderings prior to establishing, or after leaving, a definite home-range area. In plotting captures of striped field mice for purposes of estimating home ranges, irregularities in the movements of two individuals, both males, became evident. One of these individuals, we judged, moved irregularly prior to establishing a definite home range on the study area. This mouse, No. 239, was first trapped on 30 July near the northern corner of the plot. The following morning it was taken in the same trapline but 200 feet southwest of the point of first capture. Two days later this mouse was captured 535 feet east of the station where it was taken on 31 July. Sixteen additional captures revealed a home range of 1.32 acres around the point of capture on 2 August (see Fig. 1). Mouse No. 254 occupied a home range along the eastern edge of the study area. On the morning of 9 August this animal was taken almost

TABLE 1.—*Trap-revealed home ranges and distances of travel in striped field mice,* Apodemus agrarius coreae. *See text for explanation of parenthetical numbers*

FIELD NUMBER AND SEX	NUMBER OF CAPTURES	TRAP-REVEALED HOME RANGE IN ACRES	GREATEST DISTANCE IN FEET BETWEEN CAPTURES IN ANY 24-HOUR PERIOD	GREATEST DISTANCE IN FEET BETWEEN CAPTURES DURING ENTIRE STUDY
238 ♂	37	2.46	365	505
239 ♂	17 (19)	1.32 (3.86)	285 (285)	325 (565)
246 ♂	24	.71	115	155
254 ♂	10 (11)	.63 (1.32)	115 (305)	200 (335)
256 ♂	22	1.03	205	220
265 ♂	9	2.32	—	500
266 ♂	26	1.89	280	315
273 ♂	21	.63	180	180
279 ♂	16	2.41	500	700
291 ♂	7	1.43	270	410
301 ♂	18	3.59	460	630
318 ♂	21	2.41	365	560
323 ♂	7	1.36	250	380
249 ♀	11	.97	150	315
261 ♀	9	1.43	225	315
275 ♀	15	.89	150	205
289 ♀	12	1.06	150	250
298 ♀	10	.68	50	155
309 ♀	22	1.49	350	390
Average ♂ ♂	18.1	1.70 ± .25	282	391
Average ♀ ♀	13.2	1.09 ± .14	179	272

half-way across the plot in a trap 305 feet distant from the one in which it was captured on the morning of the previous day. By late afternoon of 9 August the mouse was back within its home range in a trap also 305 feet distant from the one that captured it during the night. This mouse was never again recorded within 210 feet of the trap in which it was taken in this presumed foray. Had we included all the captures of these two mice, the number of captures, home-range sizes and distances of travel would have been those shown in parentheses in Table 1.

The trap-revealed home ranges of six adult females, captured an average of 13.2 (9 to 22) times, averaged 1.09 ± .14 acres. The largest of these home ranges was 1.49 acres and the smallest, 0.68 acres. The average greatest-distance between captures of these females in any 24-hour period was nearly 66 per cent (179 as opposed to 272 feet) of the average greatest-distance between captures throughout the entire period of study.

Home ranges of male mice broadly overlapped those of other males as well as of females. Many home ranges of females overlapped those of other females but not broadly. The home ranges of two male striped field mice are shown in Fig. 1.

Populations and concentrations.—The estimated numbers of adult mice per

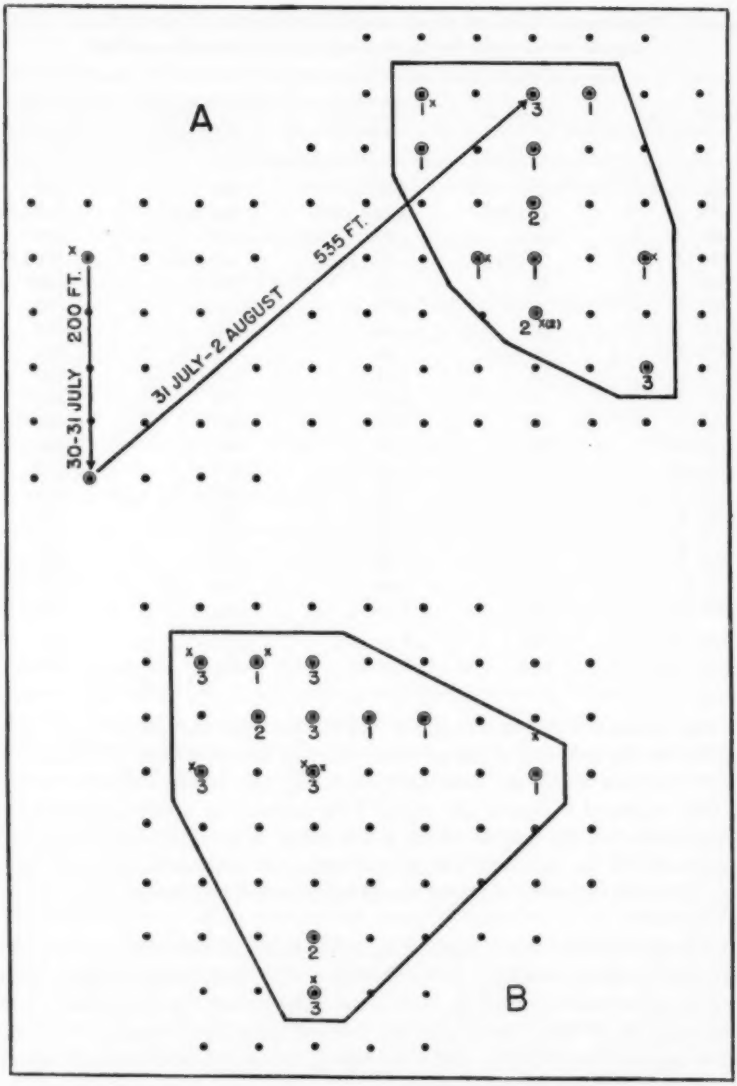

FIG. 1.—Trap-revealed home ranges of two adult male striped field mice, *Apodemus agrarius coreae*, showing *A*, mouse No. 239 whose irregular movements are discussed in the text; and *B*, mouse No. 266 who showed no irregular movements in the course of the study. Solid black circles indicate the location of trapping stations. Those that are encircled indicate traps at which the mouse was caught, the numbers below the encircled symbols indicating the number of captures in each trap. The small X's show location of holes to which the mouse

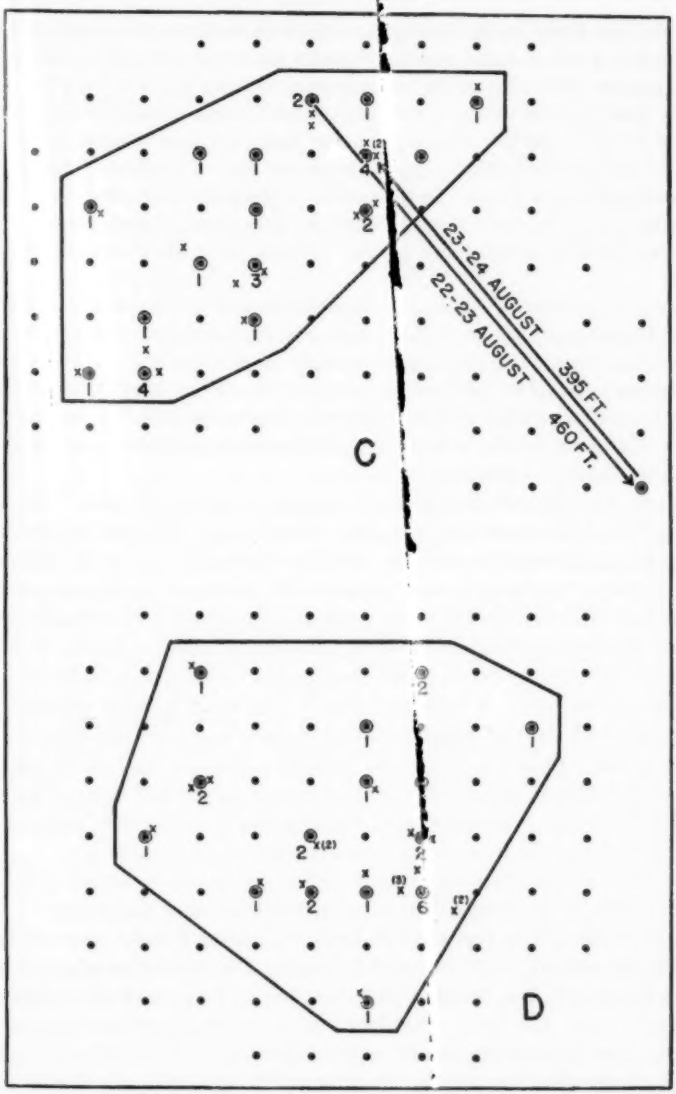

FIG. 2.—Trap-revealed home ranges of two adult male wood mice, *Apodemus peninsulae peninsulae*, showing *C*, mouse No. 240 whose irregular movements are discussed in the text; and *D*, mouse No. 269 who showed no irregular movements in the course of the study. For an explanation of the symbols see Fig. 1.

was traced. If a hole was used more than once the number of times used appears parenthetically adjacent to the symbol. The distance from one trapping station to the next was 50 feet.

acre and per home range during the period of study are recorded in Table 2. Almost half again as many males as females were trapped on the study area but our estimates show that males outnumbered females per acre only by approximately four to three owing to the larger home ranges of male mice. The numbers of resident and total males per home range are significantly larger than in females, perhaps indicating a greater tendency toward territoriality in the latter. Our examination of females in the course of the study indicated the onset of a breeding period in early August. Females presumably would show a greater tendency toward territoriality during periods when they are reproductively active.

Four juvenile striped field mice (two males and two females) were marked in the August study. One of the females was captured four times and was considered a resident. The others were considered transients.

Mice were traced to holes whenever possible. Only one of the mice listed in Table 1, a male captured 18 times, utilized a hole outside its trap-revealed home range. This hole, known to have been used once, was 25 feet outside the estimated home-range boundary.

We recorded 29 double captures involving striped field mice. On ten occasions two males were taken together. Female mice were taken together five times and a male and female were caught in the same trap on 12 different occasions. Twice female mice were trapped with adult male *Apodemus peninsulae peninsulae*. The numbers of male with male and female with female captures were in approximate proportion to the numbers of each sex known to be present on the study plot. Intraspecific antagonism between trap-mates was noted on only one occasion. A male and female that were trapped together on 25 August showed signs of fighting though neither was seriously injured. However, a young female was killed and partially eaten in a trap on 31 July by an unidentified animal, presumably another mouse, which had escaped before we checked the traps. A mouse weasel, *Mustela nivalis mosanensis*, entered a trap and killed and partly ate a young female mouse on 27 August.

Two female mice were accidentally killed while being tagged early in the study period. Six male mice died in traps in the course of the study.

Reproduction.—The first signs of breeding among females were copulation plugs in two animals on 31 July and 2 August. The copulation plug noted next was on 16 August. The female that had a plug on 2 August had another nearly two weeks later. The female that had a plug on 16 August had another on 20 August. Copulation plugs seem to be formed within 24 hours after coitus in this species. A female taken on the morning of 21 August had a bloody vaginal orifice and other external signs of recent copulation. On the morning of 22 August a copulation plug blocked the vaginal orifice. We next handled this mouse on the morning of 24 August at which time the plug was absent. Another mouse was trapped on 19 August at which time no breeding activity was evident. The same female was trapped both in the morning and afternoon of

TABLE 2.—*Population estimates of adult* Apodemus agrarius coreae

SEX	RESIDENT MICE	TRANSIENT MICE	RESIDENT MICE PER ACRE	TRANSIENT MICE PER ACRE	TOTAL MICE PER ACRE	RESIDENT MICE PER HOME RANGE	TRANSIENT MICE PER HOME RANGE	TOTAL MICE PER HOME RANGE
Male	50	22	1.95	.86	2.81	3.32	1.46	4.78
Female	30	17	1.32	.75	2.07	1.44	.82	2.26
Total	80	39	3.27	1.61	4.88			

20 August at which times a copulation plug was present. The plug was gone by the morning of 23 August, the next time this female was handled.

Of 30 resident females, 20 (66.6 per cent) were thought to be reproductively active during the last ten days of trapping. Twelve of these were recorded as pregnant, four as possibly pregnant and four had copulation plugs. One female, first recorded as pregnant on 22 August, gave birth to six young in a trap during the night of 26–27 August. Two transient females were judged as pregnant and two more as possibly pregnant. However, all were captured in peripheral or near-peripheral traps and all were taken near the end of the study period (23–26 August). Perhaps they were resident on areas bordering our study plot.

Male mice had scrotal testes throughout the month of August. The presence of juvenile mice on the plot indicated at least some early summer breeding.

October trap-off period.—Fifty-three striped field mice were snap-trapped in the three day trap-off period, 22–24 October. Twenty-one of these mice were adults; the remaining 32 were subadults and juveniles. Seventeen of the adults, three males and 14 females, had been marked in the live-trap study and of these, nine retained the metal ear tags while eight had deeply notched ears as a result of the loss of tags. Of the nine animals retaining tags, eight were females and all eight were considered resident on the plot in August. Four of these were captured within their previously estimated home ranges whereas the other four were taken within 50 feet of trapping stations where they had been taken in August. The male mouse that retained a tag was considered a transient during the live-trap study and was taken 150 feet from its nearest August trapsite. In addition, on 14 November, a former resident male was trapped incidental to other work in an area adjacent to the original plot and approximately 250 feet from its nearest August trapsite.

An adult female taken on 22 October was lactating. Thirteen other adult females taken on the same day had passed the lactation period but all had recent placental scars. The testes of all adult males taken had ascended.

***Apodemus peninsulae peninsulae* (Thomas)**

Wood mice were rather common in forested areas and on scrub hillsides and rocky slopes in central Korea. On the study area they were most common in, though not restricted to, the more densely wooded areas, frequently near gran-

ite outcroppings. Twenty adults were captured a total of 174 times. This species is evidently chiefly crepuscular and nocturnal as only 15 (all males) of the 174 captures (8.6 per cent) were made in the daytime.

Home range.—The trap-revealed home ranges of nine adult males, captured an average of 12.4 (5 to 25) times, averaged 1.88 ± .30 acres (Table 3). The largest home range was 3.73 acres and the smallest, 0.80 acres. In many cases the home ranges of males broadly overlapped each other, especially in the more densely wooded areas. They overlapped also, to some extent, the partially known ranges of females. The average greatest-distance between captures of these males in any 24-hour period was more than 71 per cent of the average greatest-distance between captures in the course of the entire study. The home ranges of two male wood mice are shown in Fig. 2.

In plotting home ranges of male wood mice we noted irregularities in the movements of two individuals, which have been excluded for the purposes of estimating home-range size. Mouse No. 250 was captured on the first day of operations in a trap on the lower border of the plot. The following morning it was taken 500 feet up the hill in the same trap line. In 16 additional captures this mouse returned no closer than 300 feet to the point of its initial capture and we have not included this initial capture in estimating the home range of this individual. Mouse No. 240 was captured 25 of 26 times in an area of 1.78 acres. On the morning of 23 August it was taken in a trap 460 feet from the place where it was captured on the previous morning. By the next morning the mouse had traveled 395 feet back into its home range. This obvious foray, perhaps exploratory in nature, was excluded in the home-range calculation (see Fig. 2). Had we included all the captures of these two mice, the number of captures, home-range sizes and distances of travel would have been those shown in parentheses in Table 3.

Five adult females were taken on the plot. All were considered residents but none was trapped enough times to estimate a home range. Distances between the two most distant captures of each of these females were, respectively, 160, 70, 210, 245, and 160 feet. One female was captured twice within one hour on the morning of 15 August in traps that were 220 feet apart. Home ranges, in so far as ascertained, of three animals that were taken at least 150 feet from the borders of the plot were, respectively, .50, .50, and .57 acres based on three, three, and four captures. These home ranges of females overlapped in only one instance. Two animals were taken in the same trap nine days apart. Neither was taken there again.

Populations and concentrations.—The estimated population density of male wood mice per acre was .57, including .46 residents and .11 transients. Residents per average home range among males were estimated to be .88 and transients .19, a total of 1.07. Because none of the resident females was trapped frequently enough to provide adequate home range data, figures of populations for females are not available. No juvenile mice were known to be on the plot.

The male that was caught 26 times utilized 15 different holes in the course of

TABLE 3.—*Trap-revealed home ranges and distances of travel in male wood mice,* Apodemus peninsulae peninsulae. *See text for explanation of parenthetical numbers*

FIELD NUMBER	NUMBER OF CAPTURES	TRAP-REVEALED HOME RANGE IN ACRES	GREATEST DISTANCE IN FEET BETWEEN CAPTURES IN ANY 24-HOUR PERIOD	GREATEST DISTANCE IN FEET BETWEEN CAPTURES DURING ENTIRE STUDY
240	25 (26)	1.78 (3.64)	325 (460)	430 (555)
241	7	.80	200	250
250	17 (18)	1.32 (2.39)	225 (500)	300 (600)
252	5	3.73	600	635
268	5	1.95	255	410
269	25	2.29	280	410
270	6	1.06	—	290
290	11	2.02	160	680
336	11	1.95	405	445
Average	12.4	1.88 ± .30	306	428

the study, all within its trap-revealed home range. Only one mouse listed in Table 3, one of the individuals trapped only five times, entered a hole outside the boundary of its trap-revealed home range. Wood mice commonly made their holes among the rocks in granite outcroppings or at the bases of trees.

We recorded five double captures involving wood mice. On three occasions two males were taken together. In one of these an animal was killed by its trap-mate, signs of a struggle being clearly evident on the survivor. Males were captured with female *Apodemus agrarius coreae* on two occasions. No female wood mice were involved in double captures.

One male was accidentally killed while being tagged on the morning of 5 August.

Reproduction.—One female was recorded as possibly pregnant on 27 August, the last day of trapping. No other breeding activity was noted among females. Males had scrotal testes throughout the month; they were small at first but were larger toward the end of August.

October trap-off period.—During the October snap-trap operations 20 individuals were taken. Seven of these were adult mice while 13 were subadults and juveniles. Four of the seven adults, two males and two females, had been previously tagged and all were considered residents in August. The two males were taken 65 and 105 feet from the borders of their August home ranges. The two females were trapped 70 and 110 feet from traps that had taken them in August. Three of the four tagged animals were not captured in the last two weeks of live-trapping. One adult female taken on 22 October was lactating. Recent reproductive activity was also evidenced by the capture of juveniles.

***Rattus rattus* subsp.**

On 13 August a young female of this species was tagged in the lower part of the plot. These rats have been known in Korea primarily from areas in or ad-

jacent to human habitations. No other individual was taken in either trapping period.

***Clethrionomys rufocanus regulus* (Thomas)**

Red-backed voles were common on talus slopes, scrub hillsides and in forested areas in central Korea. Two individuals, one male and one female, were taken on the plot in the August study period. The male, trapped on three separate occasions, ranged over a total distance of 270 feet. The female, trapped twice, was taken in traps 100 feet apart. The area covered by the female did not overlap that covered by the male. No indication of breeding was noted in the female. The male had scrotal testes in the last week of August. No red-backed voles were taken in the October trap-off period.

***Eutamias sibiricus barberi* Johnson and Jones**

Chipmunks were on the study area throughout August and 17 individuals, eight males and nine females, were live-trapped a total of 46 times. No individual was known to be present on the plot for a period exceeding ten days. Trapping records indicate a rather uniform influx of untagged individuals, along with a comparable disappearance of tagged animals. The disappearance of tagged chipmunks from the study area may have had some connection with their commercial value on the local Korean market. Perhaps, too, the home ranges of chipmunks are so large that we were obtaining records in only a part of the home range of each animal. One female chipmunk, first taken on 14 August, progressively traveled 960 feet diagonally across the plot and disappeared from the westernmost corner of the area eight days and six captures later. A female that was captured ten times in ten days near the center of the plot occupied a trap-revealed range of 1.49 acres. For nine other individuals that were trapped more than once (2 to 4 times) the average greatest-distance between captures was 235 feet (100 to 500). *Eutamias sibiricus* is an agile and rapid climber. When released at the point of capture these animals frequently took refuge in trees, occasionally climbing as high as 50 feet or more. Chipmunks were commonest where there were granite outcroppings.

In the October trap-off period six individuals, two males and four females, were shot on the plot. Only one of these, a male, had been tagged in the August study and it was shot approximately 400 feet from the site of its only capture previously. In late October chipmunks were gathering food; acorns and pine seeds were the most common contents of cheek pouches. We noted no breeding activity in either August or October.

***Crocidura lasiura thomasi* Sowerby**

An adult male white-toothed shrew was tagged near the center of the plot in the midst of a granite outcropping on 24 August, and after release the animal entered a hole at the base of the stake where the trap was set. This individual was probably a transient from the adjacent lowland; no other individual was taken on the plot.

***Crocidura suaveolens coreae* Thomas**

Of this small species, only one individual, an adult female, was trapped. It was taken near the lower border of the plot in the October trap-off period and probably wandered from the nearby streamside association, the preferred habitat of this species.

***Mustela nivalis mosanensis* Mori**

One mouse weasel, an adult male, was taken near the center of the plot on 27 August, the last day of live-trapping. It had evidently entered the trap in quest of an imprisoned *Apodemus agrarius croeae*, which it had killed and partly eaten. No other was seen on the study area.

SUMMARY

The population of small mammals in the deciduous association of a mixed forest at the Central National Forest, near Seoul, Korea, was studied by live-trapping from 30 July to 27 August 1954. The same area was snap-trapped for three consecutive days and nights in late October of the same year.

Seven species of small mammals were live-trapped during the August study and one additional species was taken in October. In the course of live-trapping, 123 striped field mice (*Apodemus agrarius coreae*) were captured a total of 857 times and 20 wood mice (*Apodemus peninsulae peninsulae*) a total of 174 times. Size of home range and size of population were estimated for both sexes of striped field mice and for male wood mice. For each of four species only one individual was taken a single time.

Some life history observations, especially breeding data, are presented for several species.

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PRENATAL SURVIVAL AND LOSS IN SOME CRICETID RODENTS

BY JAMES R. BEER, CHARLES F. MACLEOD AND LOUIS D. FRENZEL

In spite of the fact that during recent years much stress has been placed upon the dynamic aspects of mammalian populations, very little is known about prenatal survival and loss. Detailed studies of prenatal mortality in North American wild mammals appear to have been limited to the brush rabbit (Mossman, 1955), mule deer (Robinette *et al.*, 1955) and meadow vole (Hamilton, 1941). The extensive work on the wild rabbit in England has been well reviewed by Brambell (1948). Other Old World studies include work on the brown rat (Perry, 1945), common shrew (Brambell, 1935), bank vole (Brambell and Rowlands, 1936), multi-mammate mouse (Brambell and Davis, 1941), and gray squirrel (Deanesly and Parkes, 1933). The estimates of intrauterine loss in these studies, depending on what information is available, varied from 9 to 43 per cent.

This discussion presents data gathered in Minnesota between 1950 and 1955 on the meadow vole (*Microtus pennsylvanicus*), red-backed vole (*Clethrionomys gapperi*), woodland deer mouse (*Peromyscus maniculatus gracilis*) and the prairie deer mouse (*P. m. bairdii*). All of the red-backed voles and woodland deer mice and part of the meadow voles were taken from the vicinity of

Basswood Lake, Lake County, Minnesota, and all of the prairie deer mice and most of the meadow voles were taken from the Rosemount Agricultural Experiment Station in Dakota County, Minnesota.

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In order to make a thorough analysis of intrauterine mortality rates it is necessary to know the number of ova ovulated, the number that are fertilized, the number of zygotes that implant and the number of embryos that survive to parturition. Our data only partially fulfill these requirements. We are, however, able to estimate the average number of ova ovulated, the average number of embryos which implant in those animals where the complete loss of a litter has not taken place, the postimplantation mortality and the average number of young born. The data do not lend themselves to estimating the proportion of ova fertilized, the proportion of the litters which are lost in their entirety or the number of stillbirths.

The procedure was to snap-trap the animals, assuming that representative samples of the populations were being obtained. Standard measurements and weights were taken before the animals were autopsied. All pregnant females were then examined for the number of corpora in each ovary, the number of implantation sites and the number of live embryos in each uterine horn. The size of the embryos was obtained by measuring the length of the uterine enlargement during the early stages of development and the crown-rump length as soon as the embryos were developed to the extent that this could be done. Occurrence of unusual situations was recorded, such as a common placenta, which is considered to be evidence of twins; more implantation sites than corpora, which is assumed to indicate multiple ovulations from certain follicles; and disagreement in the number of corpora and implantation sites in their respective sides while the total numbers agree, which is considered to be evidence for transmigration of ova from one uterine horn to the other.

There are several obvious weaknesses in this procedure of gross observation. The reading of the ovaries may give erroneous corpora counts due to some corpora being hidden and missed. The counting of the implantation sites is normally quite easy but there is some indication that sites left by embryos which die relatively early and are resorbed may not show readily during late stages of pregnancy.

From these data it is possible to estimate the total intrauterine loss and survival in those litters which are not lost in their entirety. The subsequent discussion refers to this group. The total reproductive potential is estimated by counting the corpora and adding the number of twins and multiple ovulations observed (see Table 1). It is against this potential that the proportions of survival and loss are based.

It has not been possible to estimate the proportion of ova that were fertilized,

TABLE 1.—*Comparative reproductive data for some cricetid rodents*

	Microtus pennsylvanicus			*Clethrionomys gapperi*			*Peromyscus m. gracilis*			*Peromyscus m. bairdii*		
	Total	No. per litter	S.E.	Total	No. per litter	S.E.	Total	No. per litter	S.E.	Total	No. per litter	S.E
Pregnant mice	251	—	—	107	—	—	71	—	—	217	—	—
Corpora	1528	6.09	0.115	712	6.65	0.127	416	5.86	0.168	1251	5.77	0.079
Implantations	1432	5.72	0.109	662	6.19	0.118	387	5.45	0.101	1139	5.25	0.088
Live embryos	1404	5.59	0.110	650	6.07	0.123	378	5.32	0.108	1103	5.08	0.085
Sets of twins	5	0.02	—	1	0.01	—	2	0.03	—	1	0.01	—
Multiple ovulations	12	0.05	—	4	0.04	—	2	0.03	—	11	0.05	—
Transmigrations	17	0.07	—	5	0.05	—	5	0.07	—	27	0.12	—

so the preimplantation loss is a combination of those ova which were not fertilized and those which were fertilized and did not implant. These losses could be attributed to several factors. The former may be due to a blockage of the oviduct (Brambell, 1948) or to unsound ova while the latter may be due to inherent weaknesses in the zygote or to a failure of the uterus to develop properly. No attempt will be made to separate losses due to these causes.

The preimplantation loss is estimated by subtracting the average number of implantation sites per pregnant female from the average potential litter size. This figure does not take into account the small number of cases where preimplantation losses are not observed due to multiple ovulations or those cases where implantation sites are obscured in late stages of pregnancy.

The postimplantation loss is calculated by subtracting the per cent of preimplantation loss for those animals with embryos 5 mm. or less in length from the per cent of total loss for pregnancies with near-term embryos. This procedure eliminates the error introduced when implantation sites from resorbed embryos are missed when dealing with near-term pregnancies.

We are thus able to obtain an average potential litter size, rate of preimplantation loss, rate of postimplantation loss and an average litter size at birth.

TABLE 2.—*The effect of intrauterine mortality upon the size of the litter at birth*

	Microtus pennsylvanicus		*Clethrionomys gapperi*		*Peromyscus m. gracilis*		*Peromyscus m. bairdii*	
	No.	%	No.	%	No.	%	No.	%
Potential litter size	6.15	—	6.70	—	5.92	—	5.82	—
Preimplantation loss	0.45	7.3	0.51	7.7	0.46	7.9	0.57	9.8
Postimplantation loss	0.52	8.4	0.08	1.3	0.12	2.1	0.74	12.7
Calculated average litter size at birth	5.19	84.3	6.10	91.0	5.33	90.0	4.51	77.5

TABLE 3.—*The average number of corpora, implantation sites, and live embryos in various size-classes of* Microtus pennsylvanicus *with the per cent of pre- and postimplantation losses*

BODY LENGTH, IN MM.	NO. OF FEMALES	CORPORA	IMPLANTATION SITES	LIVE EMBRYOS	PER CENT LOSS		
					Pre-implantation	Post-implantation	Total
90–99	16	5.19	4.81	4.31	7.3	9.6	16.9
100–09	70	5.71	5.47	5.24	4.2	4.0	8.2
110–19	91	5.89	5.55	5.37	5.8	3.1	8.9
120–29	64	6.70	6.39	6.31	4.6	1.2	5.8
130–39	9	7.44	7.22	7.22	3.0	—	3.0

OBSERVATIONS

Microtus pennsylvanicus.—Two hundred and fifty-one meadow voles with implanted embryos were examined. The number of corpora varied from 3 to 12 with an average of 6.09 per pregnant female (see Table 3). The data from the Basswood and Rosemount areas were combined because there appeared to be little or no difference in the reproduction behavior of the mice from the two areas. The number of implantation sites varied from 1 to 11 with an average of 5.72. The number of live embryos showed a decrease to an average of 5.59 with extremes of 1 and 11.

The female meadow vole may start breeding when only 25 days of age (Hamilton, 1941). Observations by Gregory (1932) on domestic rabbits, Brambell and Rowlands (1936) on the bank vole (*Evotomys glareolus*), Brambell (1944) on the wild rabbit (*Arctolagus cuniculus*), and by Perry (1945) on the brown rat (*Rattus norvegicus*) have indicated that the number of ova produced at one time is correlated directly with the size of the animal. The corpora counts from our smallest *Microtus,* those with body lengths of from 90–99 mm., averaged 5.19 per pregnant female. There was a steady increase in number of corpora with increase in body length until an average count of 7.44 corpora was obtained in those females with a body length of over 130 mm. (see Table 3).

The number of implantation sites seemed to remain relatively constant until near the end of pregnancy, when the average number counted dropped. Those litters with embryos over 20 mm. in length had an average count of 5.44 sites. It appears that there was not a loss in the number of sites but rather that the sites left from embryos that die early in pregnancy were obscured by the large embryos and were not counted.

We did not estimate the age at death of the embryos undergoing resorption but it appeared that the heaviest loss came at about mid-term. There is a gradual loss in the number of live embryos to an average of 5.44 in late stages of pregnancy. Not only do we find more corpora in the larger mice but also the

average number of embryos is larger. The smaller mice averaged 4.31 live embryos while the two largest classes averaged 6.31 and 7.22 respectively. It is also evident that, while the number of corpora is greatest in the larger animals, the rate of survival is also greatest in this class. The number of live embryos is 16.9 per cent less than the number of corpora in females of the 90–99 mm. size class and only 5.8 and 3.0 per cent less in the 120–129 and 130–139 mm. size classes respectively.

Among the 1404 live embryos examined there were 5 sets of twins. There were also 12 instances that were considered to be the result of polyovuly. The number of multiple ovulations would be overestimated if some of the corpora were missed. However, the number would be underestimated wherever there was also a loss of ova before implantation. We have not been able to evaluate these factors.

Another phenomenon which is of interest, but probably has very little to do with production, is the transmigration of ova from one uterine horn to the other. Here again the estimate is a minimum figure since ova that are lost or exchanged would not be counted. Seventeen cases of apparent transmigration of ova were recorded.

Clethrionomys gapperi.—A total of 107 pregnant red-backed voles were taken from 1950 through 1955 during the months of June and July in the vicinity of Basswood Lake, Minnesota.

The number of corpora counted varied from 4 to 13 and averaged 6.65 per pregnant female (see Table 4). Unlike the meadow vole, the number of corpora did not change as the size of the animal increased. In contrast to this, however, the number of implantation sites increased from 5.90 for animals in the 90–99 mm. size class to 6.36 for the 110–119 mm. size class. The number of sites varied from 3 to 10 with an average of 6.19.

The number of live embryos varied from 3 to 10 with an average of 6.07. The number of embryos did not vary appreciably between early and late stages of

TABLE 4.—*The average number of corpora, implantation sites, and live embryos in various size-classes of* Clethrionomys gapperi *with the per cent of pre- and postimplantation losses*

BODY LENGTH, IN MM.	NO. OF FEMALES	CORPORA	IMPLANTATION SITES	LIVE EMBRYOS	PER CENT LOSS		
					Pre-implantation	Post-implantation	Total
80–89	1	5.00	5.00	5.00	—	—	
90–99	21	6.71	5.90	5.52	5.7	1.2	6.8
100–109	52	6.75	6.25	6.23	0.3	0.5	0.8
110–119	28	6.68	6.36	6.14	3.3	0.5	3.5
120–129	2	5.00	5.00	5.00			
130–139	1	8.00	8.00	8.00			

TABLE 5.—*The average number of corpora, implantation sites and live embryos in various size-classes of* Peromyscus m. gracilis *with the per cent of pre- and postimplantation losses*

BODY LENGTH, IN mm.	NO. OF FEMALES	CORPORA	IMPLANTATION SITES	LIVE EMBRYOS	PER CENT LOSS		
					Pre-implantation	Post-implantation	Total
70–79	3	5.33	5.33	5.33	0.0	0.0	0.0
80–89	18	5.83	5.39	5.17	7.6	3.8	11.3
90–99	40	5.95	5.55	5.47	6.7	1.4	8.1
100–109	7	5.71	5.29	5.00	5.4	5.1	12.4

development. Only 1.24 per cent of the embryos were calculated to be lost after implantation. While the number of corpora does not seem to vary with the size of the animal, the rate of loss and the subsequent litter size appears to be related to the animal's size. In the 90–99 mm. size class, there are nearly 18 per cent less live embryos than corpora, while in the larger females this difference amounts to but 8 per cent.

Only one set of twins was recorded among the 650 live embryos observed. There were 4 cases which suggested multiple ovulations and some 5 cases which suggested transmigration.

Peromyscus maniculatus gracilis.—The two subspecies of deer mice are handled separately since they differ in size, habits and habitat. The 71 pregnant females of this subspecies were taken in the vicinity of Basswood Lake in northern Minnesota.

The number of corpora varied from 3 to 12 with an average of 5.86 (see Table 5). Here, as with the red-backed vole, there is little or no indication of

TABLE 6.—*The average number of corpora, implantation sites, and live embryos in various size-classes of* Peromyscus m. bairdii *with the per cent of pre- and postimplantation losses*

BODY LENGTH, IN mm.	NO. OF FEMALES	CORPORA	IMPLANTATION SITES	LIVE EMBRYOS	PER CENT LOSS		
					Pre-implantation	Post-implantation	Total
65–69	1	4.00	5.00	5.00			
70–74	1	7.00	6.00	6.00			
75–79	3	5.00	5.00	5.00	0.0	0.0	0.0
80–84	42	5.57	4.81	4.74	13.7	1.3	14.9
85–89	51	5.53	4.94	4.73	10.7	3.8	14.5
90–94	81	5.89	5.46	5.26	7.3	3.4	10.7
95–99	28	5.86	5.57	5.36	5.0	3.6	8.5
100–104	8	7.37	6.87	6.87	6.8	0.0	6.8

a difference in the number of corpora between the large and small females (see Table 5).

The number of implantation sites varied from 3 to 8 with an average of 5.32. There appears to be little differential mortality which could be correlated with age or size of the female.

Two sets of twins and two cases of multiple ovulations were observed. There were also 5 observed cases of transmigration of ova to the opposite uterine horn.

Peromyscus maniculatus bairdii.—All of the 217 pregnant prairie deer mice were taken at Rosemount, Minnesota.

The average number of corpora found in this group was the smallest for any of the groups examined. The number varied from 1 to 10 with an average of 5.7. Here, as with the meadow vole, there is a general trend for an increase in the number of corpora with the increase in the size of the females. Those females in the 80-84 mm. size class averaged 5.57 corpora, and this number increased until it averaged 7.37 for the pregnant females in the 100–104 mm. size class (see Table 6).

The number of observed implantation sites varied from 2 to 9 and averaged 5.25. As in the number of corpora, the number of implantation sites increased with the size of the individual. Likewise there was a decrease in the rate of preimplantation loss with increase in size of the female. The per cent of loss varies from 13.7 to 6.8 per cent for the 80–84 and 100–104 mm. size classes, respectively.

The number of live embryos varied from 2 to 9 with an average of 5.08. There was little difference in the postimplantation loss in the females of different size classes. However, the over-all loss was much higher in the smaller classes. The smallest class showed a loss of nearly 15 per cent while loss in the largest size class was only about 7 per cent.

A single set of twins and 11 cases of multiple ovulations were observed. There were 27 observed cases of ova transmigration.

DISCUSSION

The corpora counts are the landmarks upon which all of our calculations on reproductive potential, intrauterine loss and survival and estimated litter size at birth are based. To obtain the potential litter size we add the number of twins and multiple ovulations to the number of corpora. Average potential litter sizes were found to be 6.15 for the meadow vole, 6.70 for the red-backed vole, 5.92 for the woodland deer mouse, and 5.82 for the prairie deer mouse. The preimplantation losses vary from 7.31 per cent in the meadow vole to 9.82 per cent in the prairie deer mouse. This appears to be a rather constant rate of loss from species to species. However, this rate does vary with the size (age) of the female. In general, the rate of loss was greater in the smaller (younger) females than in the larger (older) females.

The postimplantation loss seems to vary more than the preimplantation loss. This loss was observed to vary from little over one to as high as 12.7 per cent. The higher rates of loss were from the prairie deer mouse and the meadow vole.

The samples for these mice were taken throughout the breeding season while those for the red-backed vole and the woodland deer mouse were taken during the latter part of June and July which is during the middle of the breeding season. This suggests that the rates of loss are greatest at the ends of the breeding season. This was also noted in the European rabbit by Brambell and Mills (1947, 1948) who reported a slightly greater rate of loss during the early and the late portions of the breeding season than during the middle of this period. However, the data shown in Table 7 for the prairie deer mouse suggest that the reverse is true. For the most part, breeding started in April and continued through October. When the data are broken down by the month, we find that the first and last periods have total losses of about 4 and 3 per cent, respectively. During April the breeding season commences abruptly, with the bulk of the females becoming pregnant (62.5 per cent), while the October period suggests that breeding ceases in a more gradual fashion (9.5 per cent pregnant). It is difficult to come to definite conclusions as to why this should be, but it may be suggested that early in the season all of the females are relatively old animals. It has been shown (see Tables 3, 4, 5, 6) that there is a relatively low rate of loss in the larger (older) animals. It may also be suggested that the animals found to be pregnant in October were the more vigorous animals sexually and that these animals would have a relatively low rate of intrauterine loss.

The meadow voles present a slightly different picture. Breeding took place throughout most of the year. Only in March were females found not to be pregnant. The data here again suggest that the lower rates of loss were at the beginning of the breeding season. However, the sample sizes are very small during these critical periods. There is also a discrepancy in that the lowest rate of loss was recorded in October.

TABLE 7.—*Seasonal changes in rate of loss in the prairie deer mouse,* Peromyscus maniculatus bairdii

MONTH	NO. OF FEMALES EXAMINED	% PREGNANT	AVERAGE BODY LENGTH		AVERAGE NO. OF CORPORA PER PREGNANT FEMALE	AVERAGE NO. OF LIVE EMBRYOS PER PREGNANT FEMALE	% DIFFERENCE BETWEEN NO. OF CORPORA AND LIVE EMBRYOS
			Pregnant	Non-pregnant			
Jan.	20	0.0	—	82			
Feb.	14	0.0	—	81			
March	5	20.0	92	81	7.00	7.00	0.0
April	56	62.5	92	86	6.23	5.97	4.2
May	56	23.2	90	83	5.61	4.69	16.4
June	39	41.0	89	82	4.94	4.22	14.5
July	60	60.3	88	79	4.97	4.21	15.3
Aug.	72	45.8	91	79	5.78	4.94	14.9
Sept.	137	46.0	89	82	6.19	5.41	10.9
Oct.	147	9.5	88	81	5.29	5.14	2.8
Nov.	200	0.5	85	81	6.00	5.00	15.0
Dec.	30	0.0	—	81			

TABLE 8.—*Seasonal changes in rate of loss in the meadow vole,* Microtus pennsylvanicus

MONTH	NO. OF FEMALES EXAMINED	% PREGNANT	AVERAGE BODY LENGTH		AVERAGE NO. OF CORPORA PER PREGNANT FEMALE	AVERAGE NO. OF LIVE EMBRYOS PER PREGNANT FEMALE	% DIFFERENCE BETWEEN NO. OF CORPORA AND LIVE EMBRYOS
			Pregnant	Non-pregnant			
Jan.	35	14.3	107	101	4.00	3.67	8.2
Feb.	35	14.3	110	99	5.50	4.83	12.2
March	44	0.0	—	101	0.00	0.00	
April	29	72.4	108	105	5.76	5.29	8.2
May	32	62.5	114	99	7.80	7.05	9.6
June	59	62.7	109	97	7.33	6.79	19.9
July	34	41.2	112	95	5.71	5.14	10.0
Aug.	37	51.4	115	93	7.16	6.42	10.3
Sept.	24	41.7	113	96	6.40	5.70	10.9
Oct.	40	35.0	116	94	7.14	6.71	6.0
Nov.	46	19.6	111	95	5.44	4.89	10.1
Dec.	30	53.3	107	97	5.06	4.19	17.2

The postimplantation loss in the deer mouse did not vary with the size of the female while the rates of loss for meadow and red-backed voles were greatest in the smaller, and lowest in the larger classes.

The total intrauterine loss varied inversely with the size of the females in all but the woodland deer mouse. In this form there is less loss in the intermediate than in the small size classes. The loss is highest with the largest females but these were represented by only 7 pregnancies. The total loss varied from 9 to 22 per cent. The difference between the number of corpora and live embryos varied from 15 to 18 per cent in the smallest size classes and from 3 to 8 per cent in the largest classes.

The average sizes of the litters at birth for the several species examined were calculated to be about 5.2 for the meadow vole, 6.1 for the red-backed vole, 5.3 for the woodland deer mouse, and 4.5 for the prairie deer mouse.

It is necessary to have a complete knowledge of the reproductive cycle of an animal in order to evaluate the effect of prenatal mortality on the population.

The meadow vole is polyestrous and may breed through most of the year including the winter, even in such cold climates as are found in Minnesota. The females reach puberty and start to breed at about 25 days of age (Hamilton, 1941). The estrous cycle is probably about five days in length though it has not been worked out. There is a postpartum estrous, but if fertilization does not take place at this time there is a lactation anestrum. Lactation does not increase the gestation period (Bailey, 1924). Ovulation is apparently spontaneous.

The red-backed vole is polyestrous and breeds from late winter to late fall. The estrous cycle again has not been worked out but in all probability it is very short. There is a postpartum heat and the gestation period is from 17 to 19 days (Svihla, 1930).

The deer mouse is a polyestrous species which in this area breeds from the first of April to the end of October. The estrous cycle lasts about 4 to 5 days (Asdell, 1946) and the age at which the females first come into heat is about 49 days (Clark, 1938). There is a postpartum heat. The gestation period, which in nonlactating females is about 23 days, is increased as much as 10 days by lactation (Svihla, 1932).

In all of these species the gestation period is relatively short; they are polyestrous and breed through a good part of the year. It seems reasonable to assume that they have estrous cycles of about 5 days. There is a postpartum heat. In these groups it is assumed that ovulation is spontaneous.

In those forms where pseudo-pregnancy takes place after copulation—even though implantation does not take place—the complete loss of a litter may be quite important even though the species has a long breeding season and produces several litters. In this case the loss of a complete litter or two, even before implantation, could mean the loss of a litter for the season. However, in those species where the ovulation is spontaneous, the loss of a litter before implantation would mean only the delay of a single estrous period. It would take four or five such losses in the species discussed here to cause the loss of a litter to the season's production.

The loss of a complete litter, either before or after implantation, would probably be due to maternal causes. The loss of ova or embryos before implantation is fairly constant and appears to be more dependent upon a weakness in the ova or zygotes. Postimplantation loss is more variable. This variation occurs not only from individual to individual, but also with the age or size class of the female and throughout the breeding season. Much of this loss is undoubtedly due to maternal causes.

SUMMARY

A sample of 646 pregnant females from four representatives of the family Cricetidae were examined for rates of intrauterine loss of ova and embryos. It was only possible to estimate the loss for those females which did not suffer complete loss of litters. It was found that the potential litter size was smaller in small (young) females than in larger (older) females. There was also a considerably higher rate of total intrauterine loss in the small females. This loss varied from 9.0 to 22.5 per cent. The average litter size at birth was calculated to be 5.19 for *Microtus pennsylvanicus*, 6.10 for *Clethrionomys gapperi*, 5.33 for *Peromyscus maniculatus gracilis* and 4.51 for *P. m. bairdii*.

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THE USE OF BIRD BANDS ON BATS

BY HAROLD B. HITCHCOCK

The banding of bats in the United States began in a very small way in 1916 with bird bands. By the end of 1951, according to a survey by Mohr (1953), an estimated 67,403 bats had been banded in North America. In the last four years, 1952–55, bat banding has rapidly expanded. The Fish and Wildlife Service, which supplies bands for the continent, reports that for this period 92,844 bands were issued, over 36,000 in 1955 alone. Whereas the earlier banders were concerned chiefly with such aspects of the natural history of bats as their normal movements, longevity, and homing ability, the recent realization that various species of bats in the United States can transmit rabies has brought about large-scale banding operations by governmental agencies (Courter, 1954). In view of the large numbers of bats now being banded and the importance of the work

to public health because of the rabies factor, it seems appropriate to consider the wisdom of continuing the use of ordinary bird bands on bats.

It is not surprising that the simple aluminum band designed to be tightly closed about the scaled leg of a bird has not proved altogether satisfactory on the bat, for the bat's appendage is covered with delicate flesh and is complicated by the wing membrane, which must extend between the partially closed ends of the band. Bats are generally banded on the arm (Trapido and Crowe, 1946), though some of the first workers placed the band on the leg. In either position the band's sharp metal edges, especially at the corners, may cut into the wing membrane, causing flesh to grow over the ends of the band. Cases are known of bands completely buried in flesh.

Various factors influence the effect of the band on the bat. Too small a band is more likely to cause injury than a larger size. Bands that are closed carefully, with the ends parallel, and just loose enough to slide freely along the limb are, of course, less apt to give trouble than bands whose ends are not parallel or are too tightly closed to slide. Even when bands are adjusted with the greatest care, injuries are not uncommon, in some instances apparently because the bat closes the band more tightly by biting it. Many bands show tooth marks, often to such an extent that numbers become illegible. It seems likely that discomfort rather than mere annoyance is responsible for the badly mutilated bands. There appears to be a difference in the susceptibility to injury from the band by different species of bats, *Myotis*, for example, being less frequently injured than *Tadarida*.

Bands overgrown with flesh are difficult to read correctly without removing them, an operation that further injures the animal, as well as calling for the substitution of a new band on the uninjured appendage. Attempts at reading partially overgrown bands without removing them often result in the omission of one or two digits. Such errors of omission, as well as errors resulting from the misreading of digits mutilated by the bat's chewing, may render a band useless for the purposes of identification even to the investigator dealing with a known series (Cockrum, 1956: 55).

In order to get a more representative picture of the situation than was possible from my own observations on bats in the northeast, letters of inquiry were sent to eight active banders in various parts of the United States and one in Mexico. These banders all reported some trouble with the bands. Three of them felt the present bands satisfactory if applied with sufficient care. One of these banders uses specially designed pliers for closing the band about the bat's arm, but the other two close the bands by hand. The other six banders have found the bird bands definitely unsatisfactory, as a few excerpts from their replies will testify.

"Two of nine bats, banded nearly seven weeks ago and kept in captivity, show swelling of the same forearm and bleeding in one case. . . . An unmeasured but large percentage of field recoveries have been in similar condition, and many numbers were illegible from being chewed." Another investigator reported that "an inspection of about 100 preserved specimens which were sacrificed because of the highly inflamed condition of the arm around the band revealed that in

over half these specimens there was an accumulation of bat feces, loose hair, and body oil under the band, filling in the space between bone and band." From the Mexican bander came the following: "In Yucatan we have banded a colony of more than 500 specimens of *Tadarida yucatanica,* many of which were recovered afterwards by tourists and members of the maintenance personnel at the particular spot where the bats were banded, in a very poor condition."

The most careful study of banding injuries to bats seems to have been made by Richard B. Davis of the Johns Hopkins University School of Hygiene and Public Health, working in Texas on the rabies problem. The following data are from his letter to me. He examined 190 *Tadarida mexicana* one month after they had been banded. Of these, 86 showed no irritation or swelling; 104 were injured. Of the latter group, 33 were so badly injured that Davis killed them. My own observations of banded bats in the Northeast do not indicate as serious a situation as that described by Davis, but replies from banders working with *Tadarida* indicate that his experience is typical for that genus.

Is there a practical solution to this unhappy state of affairs? I believe that there is, and am indebted to two European bat banders for pointing out to me types of bands successfully used by them. Pieter Bels, a Dutch bander (*see* Bels,

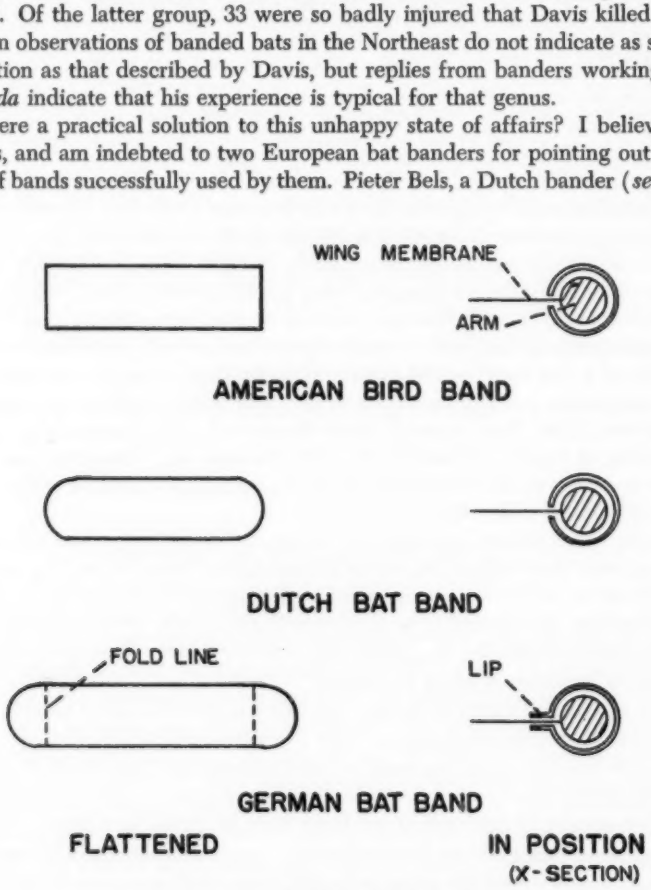

Fig 1.—Types of bands used on bats.

1952), upon seeing the frequency with which bats I had banded exhibited overgrowth of tissue, told me that he and his brother carefully rounded off the corners of the bands before attaching them to bats. Later I accompanied Dr. Willi Issel, a German bander, to a colony where he had been banding for years without seeing an injured specimen. The band used by Issel not only has the corners rounded off, but a small lip is turned up at each end so that the contact between the wing membrane and the band is through two broad surfaces rather than the band ends themselves. Figure 1 shows diagrams of the American bird band, the Dutch and the German types of bat bands.

Few banders have until recently been much concerned over the injuries brought about by banding; at any rate little mention has been made of such injuries in the literature. Much of the banding today is of species of bats that seem particularly susceptible to banding injuries. These species are being banded by the thousands, often under circumstances where it is impossible to make sure that every band is properly adjusted. And these large-scale banding projects are being carried on in studying the role of the bat in spreading rabies. It is apparent that the effectiveness of such banding, being conducted by various governmental agencies for the good of human populations, is lessened measurably by the use of improperly designed bands. The Dutch and German types of bands are known to work satisfactorily on European species. Ear tags, which Mohr (1934) has used to a limited extent in the United States, might be even superior to bands. Quite apart from the greater effectiveness of important investigations now in progress, the introduction of a better-designed band or tag will be welcome on humanitarian grounds by all who are aware of the injuries to bats caused by the type of band now employed.

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Department of Biology, Middlebury College, Middlebury, Vermont. *Received August 25, 1956.*

GENERAL NOTES

SOREX DISPAR AT MOUNTAIN LAKE, VIRGINIA

Twelve specimens of the gray long-tailed shrew were trapped at Bear Cliff, Mountain Lake, Giles County, Virginia, on July 4, 20, 21, 22 and 23, 1955, and on July 1, 3, 4 and 10, 1956. The shrews were trapped in rock crevices by means of snap traps baited with peanut butter and oatmeal. Bear Cliff (elevation 4000 feet) is an advanced xerosere with a southeastward-facing cliff composed of Silurian sandstone. The soil has collected in the larger crevices sufficiently to retain moisture and to support a scanty herbaceous vegetation with sparsely scattered deciduous trees. The specimens were trapped in the same microhabitat with *Neotoma magister* (wood rat), *Clethrionomys gapperi* (red-backed vole), *Peromyscus maniculatus nubiterrae* (deer mouse), and *Peromyscus leucopus* (white-footed mouse).

Sorex dispar has not been previously reported from Virginia. Handley and Patton (WILD MAMMALS OF VIRGINIA, 1947) note that this species is known from fifteen localities in the Appalachian Mountains from New Hampshire and New York south to southern West Virginia. They record its hypothetical occurrence in Virginia. Subsequently the southernmost limit of the known range of *S. dispar* has been extended to Sevier County, Tennessee (Conway and Pfitzer, Jour. Mamm., 33: 106–108, 1952).

The author is indebted to Dr. William H. Burt, Museum of Zoology, University of Michigan, for verifying the identification. Dr. Burt noted that the specimens are identical to *S. dispar* in every respect except the bicolored tails. He stated further that, according to the literature and the two dried specimens in his collection, the tail should be of nearly uniform color. Entire specimens preserved in formaldehyde have been deposited in the Museum of Zoology, University of Michigan; Rafinesque Museum, Mountain Lake Biological Station; and Biological Museum, Roanoke College.

This note is a contribution from the Department of Biology, Roanoke College and Mountain Lake Biological Station of the University of Virginia.—HARRY L. HOLLOWAY, *Dept. of Biology, Roanoke College, Salem, Va.* *Received August 8, 1956.*

LITTLE SPOTTED BAT IN IDAHO

On the morning of June 23, 1953, I received a telephone call from Mrs. C. W. Floyd who lives 15 miles southwest of Caldwell, Canyon County, Idaho. Mrs. Floyd stated that she had found a peculiarly colored bat in her driveway that morning. It proved to be an adult of the little spotted bat, *Euderma maculata*. So far as I know, this is the first record of this species in Idaho. Caldwell is also the farthest north this bat has been found. It may or may not be significant that there had been an unusual storm with a strong southwest wind for the two previous days. One wonders if the bat could have been carried beyond its more southern habitat by these high winds. This might also account for its exhausted condition. The animal was alive when found but died a few hours later.

The specimen is now in the Biology Department Collection at The College of Idaho in Caldwell.—HAROLD M. TUCKER, *The College of Idaho, Caldwell.* *Received September 24, 1956.*

FIRST RECORDS OF THE OCCURRENCE OF THE LONG-LEGGED BAT (*MACROPHYLLUM*) IN HONDURAS AND VENEZUELA

The rare long-legged bat, *Macrophyllum macrophyllum* Schinz, is known from two or three dozen specimens from a few localities in Brazil, British Guiana, Peru, Colombia and Panama (Sanborn, Jour. Mamm., 30: 279, 1949). Felten (Senckenbergiana Biologica, 37: 183, 1956) has recently reported it in El Salvador.

In addition to the three specimens that Goldman captured in the Panama Canal Zone (Goldman, Smithsonian Misc. Coll., 69(5): 183, 1920) there are three others in the U.S. National Museum. Two (US 260183, 260184) were obtained by Osgood and Conover at Lagunillas, Zulia, Venezuela, on May 9 and 10, 1920. The third (US 296171) was secured by Ray Greenfield near the Río Sicre, Colón, northeastern Honduras, on March 26, 1952.

Apparently remaining a mystery are the habits of this bat and the function of its peculiar posterior anatomy. Its legs, feet and claws are unusually long, and its interfemoral membrane is strikingly long and substantial. The membrane is supported by the extension of the tail to its margin and by calcanea which are longer than the tibiae. Peculiar saw-like longitudinal rows of dermal denticles adorn the posterior lower surface of the membrane.—CHARLES O. HANDLEY, JR., *U.S. National Museum.* *Received July 14, 1956.*

LONGEVITY RECORDS AND NOTES ON TOOTH WEAR OF BATS

The longevity of bats has recently been discussed by Cockrum (1956), including records of 14 years for *Myotis lucifugus* and five years for *Myotis keenii*. Our studies of hibernating bats in New England during the winter of 1955–56 have established significant new longevity records for these two species. One female *Myotis lucifugus* banded in April, 1936, in a cave in Plymouth Union, Vermont, was recovered in November, 1955, in the same cave. This bat would have a minimum age of 20.5 years, since the young of these bats are born in the summer months. Several hundred *Myotis lucifugus* were banded during the winter of 1936–37 in a mine tunnel in Chester, Massachusetts (Griffin, 1940*a*, 1940*b*, 1945). The colony in this mine tunnel was studied in detail during the winter of 1955–56 (Hall, 1956). Two male bats, which were banded in May, 1937, were recovered in November, 1955, and two more males were recovered in April, 1956. These four bats could not have been younger than 19.5 years. The one bat from Vermont and four from Massachusetts were all in good condition when recaptured and showed no visible indications of their advanced age. Two of the old bats from Chester, Massachusetts, were sacrificed for a detailed study, particularly of tooth wear and reproductive activity. Both of these old bats are preserved entire in the collection of the Department of Zoology, Univ. Mass. (Nos. 662 and 663).

One *Myotis keenii*, banded in November, 1937, in the mine at Chester, Massachusetts, was found dead in March, 1956, in the same mine. The body was partly decomposed, but a live mite was found on the body. For these reasons it is felt that this bat had died the same season and, if so, it had lived to a minimum age of 18.5 years. The skeleton of this bat is in the collection of the Department of Zoology, Univ. Mass. (No. 664).

The number of *Myotis lucifugus* banded in Chester, Massachusetts, during the winter of 1936–37 was 744. The colony in this mine was sampled adequately in the winter of 1937–38, when 61 (8 per cent) of the 774 were recaptured; in 1944–45, when again 61 (8 per cent) were recaptured; and as previously stated, in 1955–56, when 4 (0.5 per cent) were recaptured. The fact that 8 per cent of the original group were actually retaken 8 years after banding surely means that survival to an age of 8 years is commonplace. The longevity records of 19–20 years and recovery of such large numbers after eight years indicate that the average life span of the smaller insectivorous bats is much greater than previously suspected.

A study of female *Myotis lucifugus* in a summer colony at Mashpee, Massachusetts, has revealed data on longevity and reproduction. From 1934–37 the majority of the 300–400 bats in this colony were banded every summer, and considerable numbers have been caught and examined for bands almost every summer to date. Table 1 shows the number recovered nine years or more after banding. One of the females retaken after 12 years had just given birth to one young, and several of those retaken after nine years were observed with newborn young, or were nursing. This establishes the fact that female *Myotis lucifugus* may carry on normal reproductive activities at an age of 9–12 years.

TABLE 1.—*Number of female* Myotis lucifugus *retaken in the month of June nine or more years after banding in Mashpee, Massachusetts*

Time elapsed between banding and recovery, years	Minimum age, years		Number of Individuals
	Adult when banded	Juvenile when banded	
9	10		12
10	11		3
10		10	1
12	13		8
12		12	2
13	14		1

One of the purposes of studying the colony of *Myotis lucifugus* in the mine tunnel in Chester, Massachusetts, during the winter of 1955–56 was to determine the age structure of the colony, which numbered about 4,000 bats. The only method previously proposed for placing bats in increasing age groups in the field is that of Twente (1955). He used the amount of wear on the maxillary canine as an indication of age in *Myotis velifer*. He established six age groups on the basis of canine wear. These groups were: (1) tip of canine unworn and pointed, (2) tip of canine slightly worn, (3) canine worn nearly half way to the gums, (4) canine worn half way to gums, (5) canine projecting only slightly above gum, and (6) canine worn to gum line. He does not assign absolute ages to these groups, but states that the first group could contain bats only four years old or less, and groups 3 and 4 he concluded may be 5–7 years old. Christian (1953) placed *Eptesicus fuscus* in successive age groups on the basis of wear on the same tooth, and stated that in this species the canine should be worn to the gums in about eight years, in Maryland. Stegeman (1956) placed *Myotis lucifugus* in age groups on the basis of the wear on the first upper molar tooth. His figures indicate that considerable wear occurs on the molars in bats which he places as only four years old.

The teeth of the four *Myotis lucifugus* and one *Myotis keenii* which were recovered after 18–19 years at Chester, Massachusetts, were carefully examined for wear. It is believed that this is the first time tooth wear has been studied in banded bats with a definitely known minimum age. The canine teeth showed remarkably little wear, and the molars had prominent cusps showing only slightly more wear than Stegeman (1956) assigns to four-year-old bats of the same species. Using the system of Twente (1955) they seem to fit best in group 2, with the tip of the canine slightly worn, which he considers to be about five years old. His study was with a different species, however, and therefore there might possibly be difference in the rate of tooth wear. It is evident that the teeth of our 19.5-year-old *Myotis lucifugus* are still in very good condition. From these observations it is apparent that tooth wear is a highly unreliable criterion of age in *Myotis lucifugus* and *Myotis keenii* as it has previously been used.

SUMMARY

Longevity to 20.5 years in *Myotis lucifugus* and to 18.5 years in *Myotis keenii* has been established in New England. Survival to eight years is commonplace in *Myotis lucifugus*. Female *Myotis lucifugus* are capable of normal reproduction at an age of 9–12 years. Tooth wear in *Myotis lucifugus* and *Myotis keenii* is a highly unreliable criterion of age.

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JOHN S. HALL, *Mus. Nat. Hist. and Dept of Zoology, Univ. of Illinois, Urbana;* ROGER J. CLOUTIER, *Dept. of Radiation Biology, Univ. of Rochester, Rochester, New York;* AND DONALD R. GRIFFIN, *Biological Laboratories, Harvard Univ., Cambridge, Massachusetts.* *Received September 26, 1956.*

FOOD PREFERENCES OF TRINIDAD FRUIT BATS

The following is a summarization of a more detailed though preliminary study which is part of the Anti-Rabies Program currently being conducted by the Department of Agriculture of Trinidad and Tobago. It is published with the approval of the Director of Agriculture.

Trinidad fruit bats belong to the family *Phyllostomidae* and the food preferences of the three commonest species have been studied. These bats, *Artibeus jamaicensis trinitatis* Anderson, *Artibeus lituratus palmarum* Allen & Chapman, and *Carollia perspicillata perspicillata* (Linnaeus), are known to harbor rabies virus in Trinidad.

There are many more native plants which are eaten not only by these common bats but also by the rarer species. It is certain that fruit bats play an important role in seed dispersal and pollination.

Data were secured from labeled accumulations of fruit, seeds, leaves and fecal material found under the daytime and temporary nighttime digesting places of identified fruit bats. Personal observations and reports from other qualified observers included those of the bat collectors employed by the Department of Agriculture and the Port of Spain Public Health Department. Stomach analyses show little more than colored fruit pulp. Identifications of trees, fruits, seeds, etc. were made by botanists of the Imperial College of Tropical Agriculture, the Department of Agriculture and the Forestry Department.

In Table 1, the plant genera have been listed alphabetically and the local name used is

TABLE 1.—*Food preferences of* Artibeus *and* Carollia

Food plants	Season available	*Artibeus jamaicensis*	*Artibeus lituratus*	*Carollia perspicillata*
Achras zapota, Sapodilla	May–June	S,P	S,P	S,P
Anamomis umbellulifera, Monos Plum	?	P	P	
Andira inermis, Angelin	Apr.–May	S,P	S,P	
Annona muricata, Soursop	Apr.–June	P	P	
Annona squamosa, Sweetsop	Sep.–Nov.	P	P	
Bactris spp., Gri Gri Palm	July–Aug.	S,P	S,P	
Byrsonima spicata, Serrette	July–Aug.	S,P		
Calocarpum mammosum, Mamee Sapote	Aug.–Oct.	P	P	P
Carica papaya, Papaw	Jan.–Dec.	E	E	E
Cecropia peltata, Bois Canot	May–June	E,F	E,F	E,F
Cereus hexagonus, Six-angled Cactus	July–Aug.		S,P	

TABLE 1.—*Continued*

Food plants	Season available	*Artibeus jamaicensis*	*Artibeus lituratus*	*Carollia perspicillata*
Chlorophora tinctoria, Fustic	June–July	E	E	E
Chrysobalanus icaco, Fat Pork	Apr.–May	P	P	
Chrysophyllum cainito, Caimite	Apr.–May	S,P	S,P	S,P
Coccoloba uvifera, Sea Grapes	?	P	P	P
Coccothrinax spp., Broom Palm	July–Nov.		S,P	
Coffea spp., Coffee	Jan.–June	S,P	S,P	S,P
Cordia bicolor, Bois Lay Lay	May–June	S	S	
Cordia collococca, Clammy Cherry	May	P	P	
Diospyros mabola, Mabola	June–July	P	P	
Dipteryx odorata, Tonka Bean	Apr.–June	S,P	S,P	S,P
Epiphyllum hookeri, Manicou Fig	?	P	P	
Eugenia jambos, Primrose	?	S,P	S,P	S,P
Eugenia malaccensis, Pomerac	Apr.–Oct.	S,P	S,P	S,P
Ficus benjamina comosa, Ceyon Willow	May–July	E	E	E
Ficus religiosa, Peepul	June–Aug.		L	
Flacourtia indica, Governor Plum	July–Aug.	E	E	
Hylocereus lemairei, Manicou Fig	?	P	P	
Malpighia glabra, Barbados Cherry	Apr.–July	S,P	S,P	
Mammea americana, Mamee Apple	July–Aug.	P	P	
Mangifera indica, Mango	May–Nov.	S,P	S,P	S,P
Manilkara bidentata, Balata	Apr.–May	S,P	S,P	S,P
Melicocca bijuga Chenet	June–Sept.	P	P	P
Mimusops elengi, Tie Tongue	Apr.–June	S,P	S,P	
Musa spp., Banana, Fig	Jan.–Dec.	E	E	E
Passiflora quadrangularis, Granadilla	?		P	
Persea americana, Zaboca	July–Nov.	P	P	
Pimenta racemosa, Bay Tree	June–July	E		E
Piper spp., Jumbie Candle	Jan.–Dec.	E		E
Pouteria multiflora, Penny Piece	?	S,P	S,P	S,P
Psidium guajava, Guava	May–Aug. May–June	E	E	E
Putranjiva roxburghii,	Dec.–Jan.	S,P	S,P	
Roystonea oleracea, Palmiste	?		E	
Sapindus saponaria, Soap Berry	?	P		P
Sideroxylon quadrioculare, Acoma	Apr.–May	S,P	S,P	
Spondias cytherea, Golden Apple	July–Aug.	P	P	
Spondias mombin, Hog Plum	Feb.–Oct.	S,P	S,P	S,P
Terminalia catappa, Almond	May.–Aug.	S,P	S,P	S,P
Vitis vinifera, European Grape	?	E	E	

the one most frequently heard. Fruiting seasons, when known, are only approximate since there is great variation between North and South Trinidad and even within Port of Spain, the largest city. The symbols listed under the bat species indicate the part of the plant eaten, as follows: E—entire fruit (skin, pulp, seeds); S—skin only; P—pulp only; S,P—skin and pulp (no seed); F—flowers; L—leaves.—ARTHUR M. GREENHALL, *Royal Victoria Institute Museum & Department of Agriculture, Port of Spain, Trinidad, B.W.I.* *Received September 10, 1956.*

NOTES ON UTAH WEASELS

Present knowledge of the natural history, ecology and distribution of weasels in Utah is based on a small but rather steadily growing list of published records and observations. The ermine, *Mustela erminea muricus* (Bangs), is rarely collected. Literature contains references to only seven Utah specimens. Many of the locality records for the long-tailed weasel, *Mustela frenata nevadensis* Hall, are from central portions of the state (Durrant: MAMMALS OF UTAH, Univ. Kans. Publ., 1952: 419). Little is known about this mustelid in western or other arid sections of Utah. Published reproduction data on Utah weasels also are lacking.

This report contains an additional record of the ermine and new locality records and other notes on the long-tailed weasel.

An adult female ermine was taken by the writer and an associate, E. A. Shippee, on September 6, 1953, at Hickerson Park on the North Fork of Sheep Creek, elevation 9300 feet, in Dagget County near the eastern end of the Uinta Mountains. This constitutes the first specimen of this species reported from these mountains and also the easternmost locality record for the state. The specimen, University of Utah collection No. 10,951, was caught at 9 PM in a Museum Special snap-trap baited with a rolled oats–peanut butter mixture and set in a wet montane meadow dotted with clumps of willows. The position of the carcass in the trap suggested that the catch was accidental and probably did not result from attraction to the bait. A red-backed mouse, *Clethrionomys gapperi uintaensis* Doutt, with the base of its skull bitten through, was found lying near the trap. Presumably the ermine was carrying the mouse and accidentally touched the treadle of the trap. At the time these mice were common in the groves of lodgepole pine, *Pinus contorta*, immediately adjacent to the meadow. Other species of small mammals taken in the same trapline were *Peromyscus maniculatus*, *Microtus longicaudus* and *Eutamias minimus*. Measurements of this specimen (H.J.E. No. 53) are as follows: total length, 199; length of tail, 44; length of hindfoot, 25.5; height of ear from notch, 12 mm.

An adult female long-tailed weasel was taken by the writer and Donald Lewis, May 3, 1952, in Cache County, along Cottonwood Creek about one-half mile upstream from its junction with Logan River, elevation 6000 feet. The weasel was caught by the front paws in an unbaited steel trap (size 0) set at a burrow entrance under a large boulder about 35 feet from the stream. This animal was in freshly molted summer pelage; only a few white hairs of the winter fur remained along the distal half of the tail. Autopsy revealed nine large embryos which Hall (AMERICAN WEASELS, Univ. Kans. Publ., 1951: 217) records as the maximum number of young for the species. This specimen (H.J.E. No. 5) is now in the collection of the University of Southern Illinois. The embryos are in the writer's collection.

The following five records of the long-tailed weasel are from Tooele County. At the present time, the specimens are in the University of Utah Ecological Research collection at Dugway, Utah. On July 28, 1953, a large adult long-tailed weasel ran across the road at a point two and one-half miles south of Ibapah post office. After crossing ahead of the car, the weasel bounded very rapidly along the borrow pit for several yards and then turned abruptly and disappeared over a low hill into some greasewood bushes, *Sarcobatus vermiculatus*, which at that place form one of the vegetation types along the west base of the Deep Creek Mountains about 6 miles east of the Nevada boundary. West of the road hay meadows parallel a small stream about ¼ mile distant.

A large adult male was found by John Smith on June 13, 1955, along a highway in Skull Valley about three miles west of Willow Springs, where it had been killed by a vehicle. The locality is near the lower altitude limits of juniper in this area. The nearest permanent water supply is Willow Springs. This specimen (H.J.E. No. 97), which weighed 278.7 grams, had about one-half of the tail missing from an old injury.

An adult male (Ecological Research No. 6920) was collected by E. A. Shippee on September 3, 1954, near the headwaters of Clover Creek, altitude 5850 feet, on the southeast end of Stansbury Mountains. It was caught in an 18-inch Havahart trap baited with grain

and set about 100 feet from the creek in a stand of rabbitbrush, *Chrysothamnus nauseosus.*

On March 8, 1953, the writer discovered most of the left side of a lower jaw while sifting debris near the nest of a desert wood rat, *Neotoma lepida lepida,* beneath a large rock overhang at the south end of Camel Back Mountain.

Two weasel skulls were found by J. P. Newey while examining horned owl pellets for mammal remains. The pellets were collected under roosting sites in juniper trees along the base of Little Granite Mountain about 13 miles southwest of Orr's ranch. The desert habitat found in the vicinity of this and the preceding locality has generally been thought to be unsuitable for weasels. However, these skulls could have been taken by owls anywhere within the birds' home range. The lack of remains in owl pellets analyzed during studies of owl predation in other areas indicates that the long-tailed weasel is seldom preyed upon by these birds. In his study of American weasels, Hall (*op. cit.*: 200) did not record a single instance of owls as enemies of this weasel.

This work was supported in part by Army Chemical Corps contract No. DA-18-064-CML-2639, with the University of Utah.—HAROLD J. EGOSCUE, *Ecological Research, University of Utah, Dugway, Utah.* *Received September 12, 1956.*

PREGNANCY AND PARASITES OF MARTEN

Relatively little information is available in the literature regarding pregnancy, lactation period and parasites of the marten, *Martes americana.* The following observations may, therefore, be of interest. During the period April 18 to May 12, 1955, four female martens were trapped in the Chapleau Forest District by P. W. Swanson of the Department of Lands and Forests. Only one of these, caught on April 29, contained foetuses. It is estimated that these would not have been born until the middle of May. The foetuses were measured from crown to rump at the Wildlife Research Laboratory at Maple, and varied in length from 50–53 mm. There were no indications of resorbed embryos in the tract.

On June 6, 1955, I live-trapped a female marten in the same Forest District. She had seven lactating teats, three of them located on the left side of the body. The following measurements were taken of this specimen: total length, 530; tail, 150; hind foot, 81; and ear, 41 mm. This animal appeared in poor health and died within several hours after capture. No evidence of a den or of young martens could be detected near the site of capture.

Four fleas were collected from this lactating female and were identified by D. H. Pengelly. Two were *Monopsyllus vison* (Bak.). This flea has a fairly widespread distribution in Canada, where the red squirrel (*Tamiasciurus hudsonicus*) is its principal host (G. P. Holland, pers. comm.). The other two specimens were *Megabothris atrox* (Jord.) and, according to Holland (*ibid.*), they constitute the first record of this species for Ontario. Other specimens have been collected from weasel (*Mustela erminea*) and mink in Canada.—ANTOON DE VOS, *Ontario Agric. College, Guelph, Ont.* *Received August 23, 1956.*

AGE RATIOS IN WILD MINK POPULATIONS

The determination of the age of mink by use of the baculum has been discussed by Elder (Jour. Mamm., 32: 43–50, 1951) and Petrides (Amer. Midl. Nat., 43: 355–382, 1950). However, there is little information in the literature on age ratios obtained from wild mink populations by the use of this method. The only comparable information I have found is given by Lechleitner (Jour. Mamm., 35: 496–503, 1954) who found an age ratio of 28.5 adults per 100 young in 153 wild males from Montana. He states that the morphology of the baculum was reliable in all cases for distinguishing juvenile and adult age classes.

The present study began during the 1953 North Dakota trapping season when a small number of penis bones were obtained by examining discarded mink carcasses found at fur houses.

The high percentage of fur bearers bought "in the round" in this state makes the procurement of mink carcasses quite easy. In 1954 and 1955 an attempt was made to obtain a larger sample. One method used was to ask the fur buyers to save mink carcasses. Piles of these carcasses were examined whenever possible and the penis bones were removed. Some of the more cooperative fur buyers helped in this collection by asking their skinners to remove this bone at the time the mink were skinned. This collection took place during the mid–November to December 31 trapping seasons.

Bacula obtained from the various fur houses were cleaned by the use of dermestid beetles. Separation of the bones into two age classes was then readily accomplished by examining the basal portions, which in adults are encircled near the end by an obvious ridge and are much more massive in appearance than bones from young animals. Of the 2,080 penis bones examined, nearly all were readily separable into two age classes. There was some doubt on the age class involved in only six or seven individuals. These were bones which to all appearances were from juvenile animals but which were beginning to develop a dorsal protuberance. However, since none of these bacula showed the massive feature characteristics of adults, all were consigned to the juvenile class. Data on the age ratios of mink obtained during the three years is presented below.

Area	No. in 1953	Yg.–Old Ratio	No. in 1954	Yg.–Old Ratio	No. in 1955	Yg.–Old Ratio
Dickinson–Hettinger	—	—	195	4.57:1	40	4.71:1
Minot	—	—	432	4.27:1	400	5.55:1
Jamestown–Valley City	—	—	508	3.58:1	409	4.84:1
Statewide	96	4.32:1	1135	3.98:1	849	5.15:1

The sample collected in 1953 is perhaps too small to be representative but the samples from 1954 and 1955 should be sufficiently large. Bacula were collected from approximately 7 per cent of the animals harvested in 1954. While harvest figures for 1955 have not yet been determined, it is felt that at least a 15 per cent sample was secured.

The difference in age ratios for the last two years is perhaps due to the small amout of trapping done during the 1955 season. Heavy snows and thick ice prevailed over much of the state that fall and prevented trappers from taking a normal harvest. The resultant low trapping pressure probably tended to take a much higher per cent of the younger, easier-to-catch animals. This was especially true in the northern part of the state where the weather conditions were most severe. This area, represented by the 1955 Minot data, showed the highest age ratio in the state.

These figures show that each year the bulk of the trapping pressure falls on the young animals. In years when the pressure is light, such as in 1955, there is a higher survival of all animals and the next spring's breeding stock is increased accordingly. Thus one should expect a lowered age ratio among mink harvested in a year of normal trapping pressure following a year such as 1955.

This paper is a contribution from Pittman-Robertson Project W 36 R of the North Dakota Game and Fish Dept.—Edmund A. Hibbard, *N.D. Game and Fish Dept., Windsor, N.D.* *Received July 30, 1956.*

A NORTHWESTERN RECORD OF THE HOG-NOSED SKUNK, *CONEPATUS MESOLEUCUS*

The hog-nosed skunk, *Conepatus mesoleucus*, is known to occur in the southeastern quarter of Arizona, with the previously reported northwesternmost record being Fort Whipple, Yavapai County. On February 2, 1956, an immature male hog-nosed skunk was trapped in the Hualapai Mountains, Mohave County, Arizona, by the senior author. This extends the range of this species nearly 100 miles to the northwest, placing it in the western part of Arizona and less than 50 miles from California and Nevada.

This particular specimen, No. 11560 Univ. Illinois Natural History Museum, was caught 1¾ miles south of the Hualapai Mountains State Park campgrounds and about 16 miles southeast of Kingman, Arizona, at an elevation of about 6,300 feet. The skunk foraged up the steep canyon sides as well as along a ravine bottom, judging from tracks left in the snow. The habitat frequented by the skunk consisted of rocky, steep canyons with numerous intermittent springs and moist areas. A heavy growth of live oak, manzanita, New Mexican locust, Gambel oak, and willow, with scattered ponderosa pine and juniper, constitutes the main cover of the area.—William F. Musgrove and Donald F. Hoffmeister, *Mohave County Union High School, Kingman, Arizona, and Museum of Natural History, Univ. Illinois, Urbana.* *Received July 30, 1956.*

RECENT RECORDS OF CANADA LYNX IN WISCONSIN

There have been several recent occurrences of *Lynx canadensis* in Wisconsin, none of which has apparently been reported. The latest specimen was shot on December 16, 1955, in Rusk County by Glen Kresick of Ingram, Wisconsin. The lynx was killed about two miles north of Ingram in Sec. 1, T. 35 N, R. 4 W.

The last authentic record was in 1946 (Schorger, Jour. Mamm., 28: 186, 1947). Robert Wendt, of Ladysmith, was able to buy the animal for the Conservation Department. The specimen, a female, has the following measurements: total length, 830 mm.; length of tail, 90 mm.; length of hind foot, 211 mm.; ear from notch, 62 mm.; weight 19 pounds. Ear tufts were 48 mm. long. At present the specimen is at the University of Wisconsin Museum.

Another lynx was killed in Iron County by Hjalmer Pickera, of Hurley, on April 23, 1954. This individual was shot about five miles south of Hurley in Section 13, T. 45 N, R. 2 E. A study skin of the animal is in the University of Wisconsin Museum.

There have been other unverified reports recently. Dewey Yeager, Conservation Department trapper, and John Waggoner reported jumping and running a lynx on January 22, 1956, in Washburn County; the animal was not captured. This was in T. 41 and 42 N, R. 12 W. Donald Balser, game manager with the Conservation Department at Cornell, reported seeing lynx tracks in the Chequamegon National Forest in Taylor County (about twenty miles southeast of the Rusk County record) during the latter part of November, 1955. It seems probable that a low remnant population has persisted and, with the increased forest cover in northern Wisconsin, may be slowly increasing throughout this area.—Arthur D. Doll, Donald S. Balser and Robert F. Wendt, *Wisconsin Conservation Department.* *Received June 30, 1956.*

NOTES ON BREEDING AND SIZE OF YOUNG IN THE RICHARDSON GROUND SQUIRREL

In connection with a problem on endocrine-influenced behavior, supported by National Institutes of Health Grant MH-969, a large colony of Wyoming ground squirrels, *Citellus richardsonii elegans* has been maintained for several years in our vivarium. On April 9 newly captured female No. 610 was found to have a cornified vaginal smear and was placed in our standard observation cage with an active healthy male squirrel at 10:50 A.M. He immediately approached the female and sniffed her nose, backed off and shoved sawdust toward her, re-

approached and nibbled her neck and upper back. She now elevated her tail and chirruped. The male nuzzled her genital region and mounted the female at 11:08 A.M. The female whistled shrilly but did not resist. The male clasped the female from behind with his fore paws about her lower thorax. There was some palpation by the male such as is seen in the laboratory rat. After five or six pelvic thrusts the male attained intromission, the female emitted a series of low-toned chirrups, the male maintained his clasp and the animals rolled over onto their sides. The male continued to execute slow rhythmic thrusts for two and one-half minutes; he then released his clasp and crawled into a different corner of the cage where he lay for 65 seconds panting. He then sat up on his rump and cleaned his genital region with mouth and fore paws. The female now approached the male, but he warded her off with one fore paw. Observation was terminated at 11:30 AM and a vaginal smear prepared in which motile sperm were found.

The female was placed with a different male on April 10. He mounted but was unable to maintain his clasp and no sperm were found in the vagina at the end of the half-hour observation period.

On the morning of April 26 seven newborn pups were found in the female's cage. No extra-embryonic membranes or placentae were present. Three of the pups weighed five grams apiece, and four of them weighed six grams each. The litter average was 46 mm. crown–rump length.

Asdell (PATTERNS OF MAMMALIAN REPRODUCTION, 1946) lists the gestation period of *C. richardsonii* as 28 to 32 days. The facts mentioned above would give a period considerably shorter than that—one of 18 days at most. We had nine litters born in the laboratory this spring but only the one cited was from a witnessed mating. However, no litter was born to a female more than 18 days after her capture.

These litters arrived on the following days with these data being recorded as soon after parturition as possible:

Date	Number	Weights, g.	Aver. C-R length, mm.
Apr. 26	7	3–5, 4–6	46
28	5	7	47
29	9	6	46
May 1	7	6	46
2	7	5.5	45
2	7	6	46
Means	7	5.96	45.95

The mothers of the six litters listed in the table failed to care for or nurse their young which died within three days after birth. It was felt that this might have been due to the disturbance incident to the weighing and measuring of the pups. For this reason the last three litters were not handled or examined closely. Nevertheless, the undisturbed litters also died within a few days after birth.

Parturition was observed in the female which delivered her young on April 29. The process consumed 95 minutes from the time that dilatation of the vaginal orifice and a bloody discharge were observed. The five pups, probably from one uterine horn, were delivered enclosed in their extra-embryonic membranes with the chorions adherent so that they resembled a thick string of beads. The female pawed and nuzzled at the series of pups during delivery and possibly aided in the process by so doing. After delivering the first series of five, the female seemed exhausted and rested quietly for about six minutes. She then removed and ate the membranes and completed cleaning the pups. Twenty-four minutes after the first series of pups was completely delivered, the female squatted with her head close to her pelvic region and the second series of four pups appeared also encased in their membranes.

Apparently the conditions in our vivarium were not conducive to normal maternal care, as the females did not retrieve or suckle the young adequately. Four of the nine females did build nests from material provided for them, but all litters died within four days after birth.—Rollin H. Denniston II, *Department of Zoology and Physiology, University of Wyoming, Laramie.* *Received August 8, 1956.*

NEST OF THE COTTON RAT

On November 20, 1955, at a place 1⅛ miles west and 1 mile south of Lawrence, Douglas County, Kansas, four holes were found leading under a partially buried log and board. The log was approximately 6 feet in length and 8 inches in diameter. The board was approximately 7 feet in length and 2 × 10 inches in other dimensions. These holes were thought to be used by cotton rats. A live-trap was so placed that it could catch only animals coming out of these holes. Only cotton rats, *Sigmodon hispidus*, were captured in this trap. Between November 20, 1955, and December 31, 1955, six different cotton rats were thus captured, one of them six times and each of the others once. When the burrow was excavated, one large cotton rat escaped.

The excavation revealed one nest; it was round, 9¾ inches in diameter, and was composed of dried grass—chiefly blades but with a few stems and roots. The nest was found under the board. An inch of soil separated the nest from the board. Numerous droppings were found in the nest, but none elsewhere in the burrow.

The question frequently has been asked whether the hispid cotton rat builds a nest. The evidence recorded above indicates that it does.—Claude E. Hastings, *Department of Zoology, University of Kansas, Lawrence.* *Received September 18, 1956.*

RECORDS OF THE DEER MOUSE ON THE GULF COASTAL PLAIN

Only one previous report lists the deer mouse, *Peromyscus maniculatus*, as occurring on the Gulf Coastal Plain (Osgood: N. Amer. Fauna 28, 1909). An additional occurrence is reported here. Three of these mice were captured by hand on the evening of March 11, 1955, on Texas State Farm Roads 881 and 1781, about 4 miles northeast of Rockport, Aransas County, Texas. One was taken in an area of scattered live oaks and the others in an area of low shrubs and sparse grasses. The soil was sandy in both areas.

Table 1.—*Average dimensions (in mm.) in three populations of* Peromyscus maniculatus *from Texas and Oklahoma*

Character considered	Bryan Co., Oklahoma	Central Texas	Aransas Co., Texas
No. of specimens	8	6	3
Total length	128	124	121
Body length	80	73	72
Tail length	50	49	49
Hind foot length	17.6	18.2	17.7
Ear length	14.1	13.8	12.7
Femur length	14.4	13.7	13.9
Mandible length	12.2	11.9	11.5
Condyle-premaxilla length	22.1	21.6	20.9
Condyle-zygoma length	16.4	16.0	15.4
Bullar width	4.0	4.0	3.5

The mice were kept alive for approximately five months in an unsuccessful attempt to obtain breeding records. During tnis period one of the mice died, and when found was beyond preserving as a study specimen. The remainder of this report is based upon the two remaining mice plus an additional specimen which was taken by W. R. Childress 1.1 miles northwest of Rockport on December 29, 1951. This latter specimen is represented by a skin only.

Judging from available records, the population of *P. maniculatus* in southern Texas appears to consist of disjunct groups. Hence it is of interest to compare the Aransas County population with others from which mice are available, namely, with *P. m. pallescens* from Bryan County, Oklahoma, and with members of the same race from central Texas. This latter group is composed of mice from Travis, Burnet and Williamson counties. All specimens are in the Texas Natural History Collection at the University of Texas. In compiling the data, three from Oklahoma, one from central Texas and one from Aransas County are represented only by skins. Thus only their external dimensions are available.

As may be seen in Table 1, the coastal mice are smaller than either of the other populations in seven of the ten characters analyzed. They are equal to the central Texas population in body length. They exceed the Oklahoma mice in hind foot length, but average less than the central Texas population in this character. Although conclusions based upon such small series are tenuous, a clinal trend in over-all size is suggested by the data. That is, the mice are found to be larger with increasing latitude. Larger series from these localities might reveal constant differences in pelage color. The available specimens indicate that such is the case. The three Aransas County mice agree in being neither so dark nor so reddish as the specimens from the other two areas.—D. Pettus, *Colorado State Univ., Fort Collins,* and R. M. Robinson, *University of Texas, Austin.* *Received December 21, 1955.*

MELANISM IN *PEROMYSCUS BOYLEI*

Melanism has been reported for many kinds of mammals, including some rodents, but I find no record of it in *Peromyscus,* hence this report. On May 26, 1949, an entirely black adult female white-footed mouse, *Peromyscus boylei boylei* (Baird), was found in a building at the San Joaquin Experimental Range, O'Neals, California. There was no color demarcation between head, body, feet or tail. Close examination of pelage and comparison with normally colored *P. boylei* showed that the hairs were not dyed and that the animal was a true melano.

This specimen is now in the alcoholic collection of the Department of Zoology, University of California, Davis, California.—Walter E. Howard, *Field Station Administration, University of California, Davis.* *Received July 26, 1956.*

REITHRODONTOMYS BURTI IN SINALOA

In the summer of 1954 one of us (Alcorn) obtained three specimens of *Reithrodontomys burti* Benson in the state of Sinaloa, Mexico. Two of the specimens (61662, 61666 KU) were taken at a place 4 mi. N Terrero (17 mi. SSE Guamúchil) and the other (61672 KU) was taken about 20 miles to the southward at a point 1 mi. S Pericos. Previously, this species was known only from 11 mi. W Hermosillo and from Rancho de Costa Rica (near Hermosillo) in the state of Sonora (Hooper, Misc. Publ. Mus. Zool. Univ. Mich., No. 77: 43, 1952). The records from Sinaloa provide an extension of known range of approximately 350 miles to the southeastward along the coastal plains bordering the Gulf of California.

The examples of *R. burti* from Sinaloa agree with the description of this species given by Hooper (*op. cit.*: 42–43). The preauricular and postauricular areas are bright buffy, contrasting markedly with the surrounding pelage; the tarsi are entirely whitish and not dusky; the dorsal stripe of the tail is indistinctly separated from the paler ventral side; the palate slopes gradually into the pterygoid fossae; the zygomatic notch is deep; and the braincase broad (see measurements). In the Sinaloan specimens the ear averages shorter and the palate averages longer than in *R. burti* from Sonora.

At the Terrero locality these mice were trapped along the open, field side of a brush fence. The field was uncultivated. Outside the fence there was a thorn-forest association consisting of trees of from 10 to 15 feet high. The specimen from 1 mi. S Pericos was trapped in a field of agave planted in rows. Mesquite trees, head-high, were scattered over the field; between the agave plants the ground was covered with short grasses. The specimens were caught on June 9, 10, and 11, near the end of the dry season typical of this region of Mexico.

At both of the localities in Sinaloa, *R. burti* was associated with *Reithrodontomys fulvescens tenuis* Allen. Of the two species of harvest mice, *R. fulvescens* was the more common at each locality. Two specimens of *R. burti* and six of *R. fulvescens* were caught 4 mi. N Terrero. One individual of *R. burti* and nine of *R. fulvescens* were obtained 1 mi. S Pericos. Including both localities, the ratio of *R. burti* to *R. fulvescens* was 1:5.

Average and extreme measurements (in mm.) of the specimens from Sinaloa are as follows: total length, 129 (126–131); length of tail, 62 (58–66); length of hind foot, 16.7 (16–17); height of ear from notch, 14.0 (14–14); greatest length of skull, 20.4 (20.3–20.5); zygomatic breadth, 10.5 (10.0–10.9); breadth of braincase, 9.5 (9.3–9.6); depth of cranium, 7.9 (7.9–8.0); interorbital breadth, 3.1 (3.1–3.1); breadth of rostrum, 3.5 (3.4–3.3); length of bony palate, 3.9 (3.7–4.2); length of incisive foramina, 4.3 (4.1–4.6); alveolar length of maxillary tooth-row, 3.4 (3.3–3.6).—Robert J. Russell and Albert A. Alcorn, *Museum of Natural History, University of Kansas, Lawrence, and Fallon, Nevada.* *Received September 18, 1956.*

PORCUPINE BEHAVIOR IN THE DESERT-SHRUB TYPE OF ARIZONA

Encounters with the porcupine (*Erethizon dorsatum*) under treeless desert conditions are always interesting. Piñon-juniper woodland and ponderosa pine forests are its typical habitats in the Southwest (Taylor, Univ. Ariz. Biol. Sci. Bull. 3, 1935). There are few known observations for the lower and drier vegetative types. Published records are based on encounters at Bonita, Aravaipa Canyon, and the Silver Bell road in Arizona. All these localities are in the desert type and more than 10 miles from the nearest coniferous timber (Taylor, *op. cit.*). Monson (Jour. Mamm. 29: 182, 1948) recorded five observations from the Havasu Lake Wildlife Refuge about 35 miles from the higher piñon-juniper woodland. He also observed a porcupine in the Kofa Mountains in the xerophytic-shrub type about 120 miles from the closest woodland. These observations prove that porcupines are seen far away from their normal habitat.

Benson (Jour. Mamm. 34: 511–512, 1953) reported porcupines near Puerto Kino in Mexico. One was taken in a mesquite bosque, another in the paloverde type. He speculated that paloverde, paloferre and mesquite may furnish food, thereby inferring that porcupines may normally occupy desert-shrub types.

A recent observation confirms that porcupines have become adapted for survival in the desert-shrub type of the Southwest. On February 11, 1956, at approximately 10 AM, I saw a porcupine in a typical desert-shrub habitat. The animal, a male, was asleep about 10 feet above the ground in a mescat acacia (*Acacia constricta*). He was resting in the fork of branches about ¾-inch in diameter. The tail was braced on the main stem and the hind feet grasped the bases of the fork. Two small secondary lateral branches about ¼-inch in diameter were crossed beneath the chest and were grasped by the forepaws. His head rested on his right paw. Although observed at close range, he did not awaken. His sleeping position on this high perch seemed to be both secure and advantageous.

The desert-shrub habitat here is composed of a mixture of dominants including paloverde (*Cercidium* spp.), mesquite (*Prosopis juliflora*) and saguaro (*Carnegiea gigantea*). Cacti are principally prickly pear and cholla (*Opuntia* spp.). Acacias (*Acacia* spp.), spiny hackberry (*Celtis pallida*) and ocotillo (*Fouquieria splendens*) occur sparingly. The main half-shrubs are triangle bursage (*Franseria deltoidea*), littleleaf krameria (*Krameria parvifolia*) and broom snakeweed (*Gutierrezia sarothrae*). Annuals are common and include such grasses as sixweeks threeawn (*Aristida adscensionis*) and needle grama (*Bouteloua aristidoides*) and

such herbs as *Allionia* spp. and *Euphorbia* spp. The nearest ponderosa pine forests are either in the Pinal or Catalina Mountains, a distance of more than 40 miles.

Ocotillo may be an important food for porcupine in the desert-shrub of Arizona. Plants of ocotillo with bark peeled from the stem are frequently found. The bark is peeled 3 to 4 feet above the ground in sections 2 to 3 feet long. On the same day the sleeping porcupine was observed, an ocotillo with 12–24-inch pieces of stem peeled from the main plant was seen nearby. Teeth marks on the branches were too large to have been made by any rodent except a porcupine.

Use of the ocotillo for food and of mescat acacia as a resting place suggest that porcupines can survive in the desert-shrub of Arizona. Decision as to whether the habitat is year-long, seasonal or casual must await further observation and evidence.—Hudson G. Reynolds, *Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.* *Received July 11, 1956.*

LEPUS CALIFORNICUS MELANOTIS RECORD FROM SOUTHEASTERN SOUTH DAKOTA

Specimens of the black-tailed jack rabbit, *Lepus californicus melanotis*, have previously been recorded only from west of the Missouri River, in Lyman and Pennington Counties, South Dakota (James S. Findley, Nat. Hist. Misc., Chicago Acad. Sci., No. 155, p. 2, Apr. 30, 1956). In checking our Fish and Wildlife Service collection, I located a specimen, No. 263408, collected by Bjarne O. Wichmann, in Davison County (T. 101 N, R. 62 E), South Dakota, February 3, 1938, original number 28088X.

This is apparently the first record of *L. c. melanotis* east of the Missouri River in southeastern South Dakota, and evidently the most northern record of this species east of the Missouri River, and therefore merits recording.—Viola S. Schantz, *U.S. Fish and Wildlife Service, Washington 25, D.C.* *Received July 20, 1956.*

THE GESTATION PERIOD OF THE TWO-TOED SLOTH

An observation of minimal gestation period for a single specimen of the two-toed sloth, *Choloepus didactylus*, was recorded at the Detroit Zoological Park. Asdell (PATTERNS OF MAMMALIAN REPRODUCTION, 1946) reports the gestation period of a species of three-toed sloth, *Bradypus griseus*, to be four to six months. Since little additional information is available on this rather heterogeneous order, this observation seems worthy of record.

Three two-toed sloths were received at the zoological park in 1955—a single specimen on May 5 and two additional animals on May 11. One of the latter pair died on the same day it arrived at the park. The remaining two sloths were placed in the same exhibit and remained together until June 3, 1955, when one of them died. Post-mortem examination revealed it to be a male.

The remaining animal was maintained alone without further contact with others of its species. On February 22, 1956, it gave birth to a single young, 263 days after the death of the male. The young sloth was not observed to leave the protection of its mother's body until mid-July, although it had begun eating solid food within a month after its birth.—Walter D. Stone, *Detroit Zoological Park, Royal Oak, Michigan.* *Received August 13, 1956.*

ANOMALOUS CANINE TOOTH DEVELOPMENT IN AN ARIZONA PECCARY

An adult female peccary (*Pecari tajacu sonoriensis*) was killed by archer John E. Simon in the Tucson Mountains, Pima County, Arizona, on February 19, 1956, during the regular hunting season. Anomalous development was present in the lower left canine tooth. When a small portion of the lower jaw was cut away the position of the canine was clearly visible. The tooth bud had apparently divided into three parts during development. One part grew upward and formed a small, malformed lower left canine approximately one-third normal size. The root of this malformed left canine extended forward and was in contact with the root of the right canine tooth. The second and third parts of the tooth bud grew upward and then turned downward penetrating the lower jaw. The second part protruded 16 mm. beyond the lower edge of the jaw bone. The third part protruded 5 mm. adjacent to the second part.

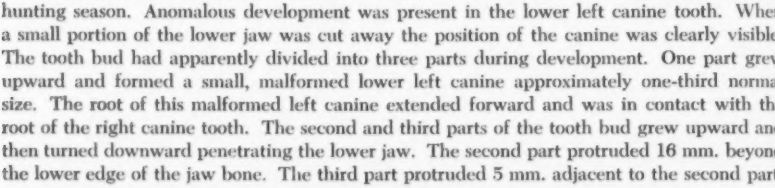

PLATE I

Jaw of peccary showing anomalous tooth development (right) and the normal jaw of a peccary (left).

The smaller, lower left canine resulted in uneven wear on the incisors, canines, premolars and molars, causing poor alignment of the tooth rows. Plate I shows this condition after a small portion of the jawbone had been cut away, compared with that of a normal peccary jaw. Mr. Simon stated that the fleshy part of the lower jaw had an enlarged lump on it which he found to be infected upon examination.—Bobby J. Neal and Ralph D. Kirkpatrick, *Arizona Cooperative Wildlife Research Unit, University of Arizona, Tucson.* *Received September 25, 1956.*

PARTURITION AND EARLY REACTIONS OF WHITE-TAILED DEER FAWNS

Although literature is replete with information on the life history of many animals, records of the process of parturition and the early reactions of young are rare. Life at this stage may hang in a critical balance for both fawn and doe. For these reasons records were made on the parturition and early moments of life of the white-tailed deer, *Odocoileus virginianus*.

In a study of the breeding season, gestation period and growth of fawns, three to four adult does were kept in small pens at the Alabama Cooperative Wildlife Research Unit Headquarters. A 5-year-old doe, "Tater," was expected to fawn early in July, 1955. At 4:30 PM on July 11, the doe was noted nervously moving about the pen. She alternately stopped and walked, with her tail held straight out, and appeared to be straining slightly. At 5:08 PM she lay down with tail still held horizontally. Labor pains were obvious and were recurring

at 3-second intervals. After arising and lying down again, the pains recurred at 2-second and then 1-second intervals. Thirteen minutes elapsed from the first obvious straining until the fawn was born. As soon as the head passed through the vulva, the entire body emerged in not more than 3 seconds. The umbilical cord apparently broke as the doe arose following the passing of the fawn. She immediately started licking the fawn. Eight minutes later a second fawn was born with equal rapidity and was breathing within 20 seconds.

Nursing by the first fawn started only 8¾ minutes after birth, but the second did not find a teat until a lapse of 32 minutes after it was born. They were able to arise and stand wobbling on their own feet when 19 and 23½ minutes old, respectively. The slippery concrete floor of the pen probably delayed their standing up by at least 5 minutes as they repeatedly collapsed because their hooves slipped in early attempts to stand. At birth the bottoms of the hooves had yellowish, jelly-like, convex-shaped pads that changed to a darker creamy color in a matter of a few minutes.

The doe used her teeth to pull from the vagina the afterbirth. All membranes were eaten by the doe within 29 minutes after the second fawn was born. The umbilical cord of each fawn was broken at the body with no noticeable remnant.

One of the fawns was noted to defecate a yellowish fluid when 49 minutes old. The defecation seemed to be stimulated by the doe licking the inguinal region. At this age (49 minutes) the fawn shook its skin like a wet dog.

The noise of a car passing in the street about 75 yards distant caused both fawns to cock their ears when they were 28 and 46 minutes old, respectively. A fawn from another doe responded similarly when 1¼ hours old. The doe paid no attention to the observers, who remained quiet 5 or 6 feet from her during the births. No vocal sounds were made by either the doe or the fawns.

The entire process of the birth was rapid, and seemingly bloodless. It appeared that the doe was intent on eliminating all traces of wastes that might attract predators. The prompt eating and licking-up of waste tissues and fluid doubtless has survival value in the wild. During parturition and shortly thereafter the hair on the metatarsal glands of the doe came to a point, indicating no activity of that gland. At times of fright, the hair on these glands has been noted to be erect. In a matter of one-half hour after the onset of labor pains, she could have dashed off to lead a predator away from her fawns and thereby save them.

Fawns less than 4 days old remained quite relaxed and offered little resistance when handled for weighing and measuring. From 4 days on, however, they resisted handling with increasing vigor and determination.—Arnold O. Haugen and Daniel W. Speake, *Alabama Cooperative Wildlife Research Unit, Auburn, Alabama.* *Received August 20, 1956.*

POSSIBLE OCCURRENCE OF IDENTICAL TWINS IN THE WHITETAIL DEER

A possible occurrence of identical twins in the whitetail deer was observed while the writer was employed by the New Hampshire Fish and Game Department. Uteri with attached ovaries were collected at various checking stations during the hunting season and were preserved in weak formalin solution. One such set of reproductive organs was taken from a 4½-year-old doe killed 30 December 1951 in the town of Deerfield in southern New Hampshire. This doe dressed out to 94 pounds and was rated in good condition.

The ovaries were hand-sliced in the manner described by Cheatum (Cornell Veterinarian, 39: 282–291, 1949) and each thin section was examined. Two small corpora rubra, one in each ovary, were observed, as well as several Graafian follicles about 5 mm. in diameter. No lutinized follicles were present. Two well-formed corpora lutea were found in the right ovary. These were 8 mm. in diameter and had very small centers. There were no corpora lutea in the left ovary. One embryo, 8.5 mm. long, was found in the left horn of the uterus, and two smaller embryos, 6.2 and 6.3 mm. long, were present in the right uterine horn. These latter two embryos lay very close to each other and were enclosed in the same mucous sheath that appeared to be a common chorionic membrane. The embryos were too small to sex.

The incidence of identical twins in the whitetail deer is unknown. However, the occurrence of identical twins would not necessarily show up in an ovarian study. For example, two follicles rupture in a deer, releasing two ova. One ovum becomes fertilized and divides into two to form two zygotes, while the other ovum fails to become fertilized, dies, or is otherwise lost. There is no indication to the game biologist that this is a case of identical twins—two corpora lutea and two embryos.

The fact that in the present case there were three embryos in the uterus and only two corpora lutea in the ovaries would strongly indicate that one of the two indicated ova had undergone mitotic division subsequent to being released from the ovary. Corroborative evidence of this thesis is seen in the relative sizes of the embryos—two very similar in size and the other one some 20 per cent larger. The relative location of the embryos in the uterus and the common enclosing membranes of the two smaller embryos tend to further strengthen the thesis that this was a case of identical twins.

There exists another possibility. This is that one of the corpora lutea developed from a polyovular follicle. It is impossible at this late date to determine whether or not this had been the case. However, the two corpora lutea were very similar in size and shape. They each had a small centrally located center indicating that the luteal tissue had developed centripetally from the follicular walls. If one of the follicles had been polyovular, it is quite likely that there would have been either two centers or one grossly displaced center in the corpus luteum. —ROBERT A. MCCULLOUGH, *Box 639, Dugway Proving Ground, Dugway, Utah.* *Received October 10, 1956.*

ROE DEER IN NEW YORK

There appear to be no roe deer at present in any American zoological park, a situation due largely to the stringent federal regulations pertaining to the introduction of ungulate stock. Around the turn of the century there were reports of roe deer, *Capreolus capreolus*, released by sportsmen on certain ranches in this country, but these introductions apparently met with indifferent success; some of the animals soon disappeared, while others survived but failed to reproduce. In a recent paper (Zoologica, 41: 173–174, 1956), those which failed to survive were ascribed to Siberia; others on the Rickenbacker ranch in Texas, which survived but did not spread, were possibly of European origin.

In view of this, it was with some surprise that I heard the report that roe deer existed on the estate of Walter Teagle, Jr., near Millbrook, central Dutchess County, New York. On 17 April 1956, at the invitation of Mr. Teagle, I visited the area with Leonard J. Goss, veterinarian at the Bronx Zoo. The estate comprises several thousand acres of rolling country, cleared lands interspersed with hardwood stands, and with several small lakes and streams. At one time much of the property was cultivated or devoted to dairy herds, but it is now reverting to brushland and forest, and the fencing about the area is in disrepair. Native whitetail deer were in evidence everywhere, as well as gray squirrels and cottontails; ring-necked pheasants, which are propogated here, were conspicuous and abundant.

Under the guidance of the caretaker, a Scotsman who had lived here for some thirty years, we did indeed see two or three animals, segregated from the rest, that appeared to be true roe deer. Antlers were of course shed at this season, but the deer were of small stature, with greatly abbreviated tails and light rump patches. Our guide had known the species in Great Britain and was convinced of their identity. He seemed well acquainted with their local haunts, always quite separate from those of the native deer, and their distinctive habits and appearance. Occasionally in winter they come in for food from the kitchens. We learned that several had been introduced from Europe about 1900, that they had roamed freely over the estate but never moved outside, and that they had at one time increased to several dozen in number. At present they are reputed to number about six, and breeding is said to have occurred as recently as last year.—RICHARD H. MANVILLE, *151 Ossining Road, Pleasantville, N. Y.* *Received July 12, 1956.*

A CRYPTORCHID ROCKY MOUNTAIN MULE DEER

On September 23, 1953, a Rocky Mountain mule deer (*Odocoileus h. hemionus*) was killed one mile west of Loyalton, Sierra County, California, by Mr. K. Brown of Loyalton. Mr. Brown noticed an abnormality in the external genitalia of the deer and subsequently gave the hide to the senior author.

Upon examination, the cryptorchid condition was noted. The scrotum was rudimentary, measuring 30 mm. in length and 12 mm. in diameter. It was black and hard with the walls compressed so as to leave no atrium. The deer, a 2-year-old, appeared to be normal in all other respects. The antlers were hard with two points on either side, measuring 15⅞ inches high with a spread of 12½ inches, and a beam diameter of 1 inch.—Don E. Beauchamp and Fred L. Jones, *California Department of Fish and Game. Received August 9, 1956.*

A NOTE ON THE SONORAN PRONGHORN

Over thirty years ago, Nelson (Status of the pronghorned antelope, 1922–1924, USDA Bull. 1346, 1925) reported 75 and 32 antelope, *Antilocapra americana*, in Yuma and Pima counties, respectively, of extreme southwestern Arizona. The description of these animals as *sonoriensis* by Goldman in 1945 (Proc. Biol. Soc. Wash., 58: 3–4) focuses attention on the scarcity of this variety in the United States. The pronghorns of south-central Arizona have been diluted by transplants from northern Arizona (Halloran, Ariz. Wildlife-Sportsman, 25(4): 26–28, April 1954). This leaves the herd that ranges on and adjacent to the Cabeza Prieta Game Range and the Organ Pipe Cactus National Monument of southern Pima and Yuma counties as the only pure Sonoran pronghorn in the United States. This scattered population, which is estimated to be less than 100 in number, also is known to range into northern Mexico where a recently constructed highway between the towns of Sonoita and San Luis in Sonora opens up this barren desert area to a small but constantly growing stream of traffic.—Arthur F. Halloran, *U.S. Fish and Wildlife Service, Cache, Oklahoma. Received August 23, 1956.*

SERUM MAGNESIUM CHANGES IN COLD-EXPOSED MAMMALS

Hibernation and hypothermia have been subjects of increasing interest in recent years, yet there is a dearth of observations on the biochemistry of these states. High levels of magnesium in serum have been related by several investigators to hibernation and cold exposure[1,2,3]. In the present studies an active rise in the serum level of magnesium was found with hibernation or winter rest in three orders of mammals. Serum magnesium and hematological data were obtained on two species of bats, thirteen-lined ground squirrels and golden hamsters, and the black bear. Hibernating and non-hibernating conditions were included. Magnesium levels as determined by the method of Orange and Rhein[4] were observed to be consistently higher during hibernation than in active animals. The percentage increase in the serum magnesium varied with the species studied: little brown bat, *Myotis lucifugus*, 62 per cent; big brown bat, *Eptesicus fuscus*, 53 per cent; thirteen-lined ground squirrel, *Citellus tridecemlineatus*, 65 per cent; golden hamster, *Mesocricetus auratus*, 25 per cent; and black bear, *Ursus americanus*, in winter rest, 29 per cent. The mean values in milligrams per one hundred milliliters of serum, for active and hibernating animals respectively, are given in Table 1. In contrast to these changes indicated above, cold exposure without hibernation or winter rest did not elevate the serum magnesium. The serum specific gravity and blood hematocrit occasionally increased with hibernation, but not consistently, thereby indicating the rise in the serum magnesium to be an active process.

[1] Suomalainen, P., Ann. Acad. Sci. Fennicae, A, 53, 1 (1939).
[2] Platner, W. W., and M. J. Hosko, Amer. Jour. Physiol., 174, 273 (1953).
[3] McBirnie, K. E., F. G. Pearson, G. A. Trusler, H. H. Karachi and W. G. Bigelow, Canad. Jour. Med. Sci., 31, 421 (1935).
[4] Orange, M., and H. C. Rhein, Jour. Biol. Chem., 189, 379 (1951).

Some of the details of the change in serum magnesium were determined using little brown bats. The elevation of serum magnesium occurred after only one to two hours of hibernation and was found by the time the esophageal temperature had dropped to 13° C. There was no significant serum magnesium increase when esophageal temperature had dropped to only 17° C. Awakening from hibernation does not require a lowering of the serum magnesium since there was no reduction of serum magnesium when body temperature was raised to 18° C. One hour after arousal from hibernation the serum magnesium had dropped to the level typical of active animals.

TABLE 1.—*Serum magnesium levels in hibernation and winter rest*
(All values are milligrams per one hundred milliliters of serum.)

	Little brown bat	Big brown bat (4 days)	Thirteen-lined ground squirrel	Golden hamster	Black bear	Hedgehog (Ref. 1)	Woodchuck (Ref. 3)
			Active				
Magnesium							
Mean	4.38	4.78	3.65	4.03	3.81	3.2	2.8
Std. dev.	0.16	0.61	0.41	0.10	0.21	—	0.46
No. deter.	36	10	8	2	2	—	4
			Hibernating				
	(2 days)	(2 days)	(2 days)	(2 days)	(1 mo.) Inactive		
Magnesium							
Mean	7.11	7.32	6.05	5.01	4.85	6.0	4.4
Std. dev.	0.13	0.60	0.31	0.07	—	—	0.31
No. deter.	15	6	4	2	1	—	4

This research was made possible by a grant from the National Science Foundation. Some of the animals were obtained with the kind assistance of Dr. Glen C. Sanderson of the Iowa State Department of Conservation. The serum of the black bears was obtained with obvious difficulty by Dr. Raymond J. Hock and sent packed in ice from the Arctic Health Research Center, Anchorage, Alaska. The details of this investigation will be published in separate accounts elsewhere, but the combined data presented here indicate that elevated serum magnesium may be as characteristic of hibernation as lowered body temperature and metabolism.
—M. L. RIEDESEL AND G. E. FOLK, JR., *Dept. of Occupational Health, Univ. of Pittsburgh, Pittsburgh, Pa. and Dept of Physiology, State Univ. of Iowa, Iowa City.* *Received August 13, 1956.*

PERSONAL NOTICES

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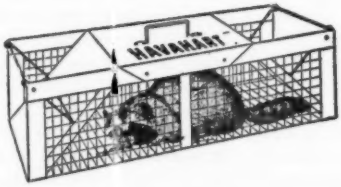
HAVAHART HUMANE ANIMAL TRAPS



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REVIEWS

Barnes, Claude T. THE NATURAL HISTORY OF A WASATCH SUMMER. The Ralton Co., Salt Lake City, Utah. 100 pp. 1957. Price, $3.00.

Here is the first of a contemplated series to cover the four seasons in the Wasatch Mountains of northern Utah. In no sense a technical treatise, it consists of excerpts from the author's journal, one page for each day from June 21 to September 22. The writer, a lawyer by profession (and a Charter Member of our Society), has lived for over twenty years in the foothills of these mountains. During leisure time he has explored the surrounding country, ever alert for "anything new or outstanding in flower, feather or fur." Recording his observations has been a "delightful diversion from multiform duties, but in a broader sense it is but a token of the love of a naturalist for the beauties and mysteries of the wild woods." He here passes on to others his thoughts on trees and flowers, snakes and insects. With him we watch white-throated swifts high on the slopes of Timpanogas Peak, we listen to the chattering ouzel foraging along a mountain stream, or we savor the "redolence of spicy gray sage" on the plains. And we, too, come to feel that these mountains "mean tranquility, and purity, the very life of man's reverential quest of the Infinite."

Interspersed throughout are frequent observations on most of the local mammals. There are discussions of porcupines and mountain lions, coyotes and pocket gophers, elk and grizzly bear. Frequent allusions are made to Indian customs and legends. We read the recipe for a jack rabbit stew *à la Ute*, complete with lizards and grasshoppers, and seasoned with roasted ants. We learn how the skunk derived its name from the Indian *segankw*, later transposed as *squinck*. An interesting account of the water shrew and its kin—"wondrous imps of mystery and superstition"—tells of the respect in which they were held by the Indians, who thought them capable of darting into one's vitals. Apparently a similar belief prevailed in England where, in 1545, Elyot wrote of "a kynde of myse called a shrew, whyche yf it goo ouer a beastes backe, he shall be lame in the chyne." These are entertaining accounts, and woven into them are bits of the philosophy of an appreciative observer.

The volume is fraught with more than its quota of typographical errors, and is somewhat overburdened perhaps with mere lists of flora and fauna, each species with its technical name properly appended. An index might have proved useful.—RICHARD H. MANVILLE.

Bee, James W. and E. Raymond Hall. MAMMALS OF NORTHERN ALASKA: ON THE ARCTIC SLOPE. Univ. Kansas Mus. Nat. Hist. Misc. Publ. No. 8. 309 pp., 5 pl., 1 colored. March 10, 1956. Price $1.00 (paper), $4.00 (cloth).

On a day in July, of the year 1741, Georg Wilhelm Steller, the German naturalist attached to Vitus Bering's expedition of discovery, stepped ashore on Alaskan soil near Cape St. Elias. The occasion marked the culmination of four long years of hard work and arduous travel, and it was unfortunate that Steller was able to spend less than ten hours ashore, observing the flora and fauna of this unknown part of the New World. Scientists nowadays fare better, and literally hundreds have been able to conduct field research in Alaska during the last ten years, under the sponsorship of government agencies and various other organizations. The U.S. Navy's Arctic Research Laboratory at Barrow has played a major role in supporting field work in the Alaskan Arctic, primarily during the summer months, and the attractive new book MAMMALS OF NORTHERN ALASKA presents the results of one such field study. It is an excellent example of the extent to which scientists can capitalize upon the opportunity for even limited field work in the Arctic, but its several deficiencies illustrate the ease with which perspective and a sense of proportion may be lost under the modern come-and-go research programs.

The book is composed of a 4-page Introduction, a 2-page Check List of the Mammals of the Arctic Slope of Northern Alaska, accounts of the individual species or subspecies (248

pp.), a Key to the Species (12 pp.), and a final section of 23 pages covering Characteristics of the Mammalian Fauna, Geography and Climate, Northern Arctic Slope *versus* Southern Arctic Alpine Areas, Biotic Communities, Itinerary, and Acknowledgments. A section of Literature Cited concludes the volume with 174 titles.

The report covers the area from the crest of the Brooks Range north to and including the coastal waters of the Arctic Ocean. For each of the 41 species or subspecies (including *Lemmus trimucronatus subarcticus*, new subspecies described here) known to occur in the area, the plan of treatment is the same: the scientific name, common name, an Eskimo name, a complete synonymy, a description, a list and map of records of occurrence, and a group of skull drawings; for all land mammals there is an additional section of Remarks, which varies in length from a short paragraph on the land otter to 42 pages for the brown lemming. Six additional mammals possibly occurring on the Arctic Slope are mentioned.

The book is a strange blend of meticulous measurements and careful observations, diluted with sweeping generalizations, and liberally sprinkled with hearsay and unsupported opinions. One gets to know Pete Savaglik (an Eskimo field assistant) rather well during the course of the book. Alaskans will also have the opportunity to read, scattered throughout the book, the opinions and assertions of some of their acquaintances; unfortunately without the screening and evaluation that one has learned through first-hand experience must be applied to some of them.

It is difficult to understand why so much second-, and even third-hand information should appear in a work of this sort. It creates an atmosphere in the grand tradition of scientific exploring, but seems out of place in this day of modern communication and intensified Arctic research. Steller's few hours of observation in the New World were priceless, but science in Alaska has come a long way in 200 years, and no longer does every field note or conjecture warrant publication. It was one thing for MacKenzie, in the 18th Century, to record in detail what the inhabitants of the unknown Far North told him about the fauna, but quite another thing for Bee and Hall to publish, for example, the misconceptions of a bush pilot in explaining the habits of northeastern Alaska caribou. A preliminary report of extensive cooperative studies of this very subject, by the United States and Canadian Wildlife Services, has been available in Fairbanks for several years and could have been had for the asking. Surely the authors must have known there was information on caribou available other than hearsay.

This mental isolation has too often characterized the work of traveling scientists in Alaska, and it is apparently not a new development. William Healy Dall, writing on the same subject almost fifty years ago, pointedly commented (Harriman Alaska Ser., vol. 2, p. 204): "To one conversant with the facts, one of the most amusing things in current literature is the placid innocence of many a casual traveler or gold hunter, who pours out his tale of experiences in the confident belief that nothing of the kind is on record."

Had the authors confined their work to the quantitative data actually in hand, the book would seem less pretentious, and a number of errors would have been avoided. The authors state, for instance, that an informant at Umiat "told us" the Fish and Wildlife Service had killed 275 wolves, including foetuses, east and south of Umiat in February and March of 1952; and that later in the spring of the same year 74 females and 86 males were taken. The official record of this operation, available for the asking, shows that a known kill of 259 wolves was made near Umiat between March 21 and May 8, 1952, and that the females examined contained an additional 74 foetuses, for a total of 333 wolves. There is no record of the additional 74 and 86. There is little excuse for not obtaining the correct figures, if they were to be quoted.

One may also question the value of distribution records based on hearsay. When this practice is followed, it must be realized that the distributions shown more nearly reflect the number and experience of people contacted (and their reliability) than the distribution of the mammals themselves. Unfortunately, or perhaps fortunately, the authors obtained

but a small sample of this type of information from all that was available. They apparently did not consult the report of a study of Dall sheep distribution in Alaska previously accomplished under Arctic Institute sponsorship, and on file in the Office of Naval Research.

Biologists who have studied caribou will find many statements they may question. The generalization that caribou "wander erratically" will be news to those who have repeatedly witnessed the purposeful spring "migration" of female and young caribou to and from a calving area. On one page, the reader is told that "there are no main herds" of caribou, but six lines later he finds another statement to the effect that "there are large herds" which retain their identity. Previously published discussions of this matter are not cited. Repeated mention of various effects of "overgrazing" by caribou is a reminder, also, that this has never been demonstrated to our knowledge except where reindeer or caribou were confined by herding or insular location. Nor is there any indication that the authors have decided how they would recognize or measure "overgrazing." An interesting chart is given, portraying a speculative history of wolf-caribou-man relationships in Arctic Alaska. The present trend of increasing caribou numbers is shown to begin about 1940 and, oddly enough, to coincide with the high point in wolf numbers. The chart indicates at that time a ratio of 1 wolf to each 5 to 10 caribou! A rather puzzling reference is also made to "natural cyclic fluctuation" of caribou, beyond the alleged overgrazing and other possible population depressants. In the discussion of another large mammal, the Dall sheep, the authors state that the "rut" was apparently in full swing in August, which is roughly three months earlier than it is known to occur in this species in Alaska. Rams do butt heads year-round, however.

These illustrations seem to indicate that there is difficulty in the transition from mouse trap to caribou populations, and yet even some fundamental matters of population dynamics in small mammals seem to have eluded the authors. It is stated on one occasion that lemmings increase in "mathematical ratio"; and in "arithmetic progression" on another, neither of which statements expresses the meaning that was probably intended.

After losing confidence in the judgment of the authors on several ascertainable subjects, their judgment respecting the complicated ecology of wolf-caribou relationships may rightfully be suspect. Lengthly editorializing on this subject appears in the book, but again without the supporting facts that would be necessary to even partially substantiate their rather dogmatic assertions. Scientific objectivity is deserted in what appears to the reviewers to be a naïve and almost pathetic attempt to interpret fragmentary observations and quote selected opinions to demonstrate the completely sanitary nature of wolf predation upon caribou. Predator control policies anywhere can and should be freely debated, as such, but the authors have adopted as extreme and unfounded a view of the basic ecological problem as have the other extremists who believe that the only good wolf is a dead wolf.

The technical aspects of the book also leave some things to be desired. Great use is made of mean values of samples, and regressions of various sorts, but seldom is there any indication of the variance involved, or the reliability of sample means. One is disappointed, too, in discovering that the caribou skull figured is one from Greenland, rather than Alaska.

The treatment of systematics is very thorough, and often not in agreement with other recently published material for the area. The problem of differentiation in forms separated by Bering Strait is discussed at length in connection with *Dicrostonyx*. The authors feel that there is as yet insufficient evidence to warrent the synonymy proposed by Rausch.

The book is printed on a good grade of paper, is relatively free of typographical or other mechanical errors, and is well bound in either paper or cloth. The colored plate of shrews, voles and lemmings done by R. P. Grossenheider is up to his usual standards. The ingenious use of graphs and charts has added much to the publication. The drawings of skulls are exceptionally well done, and clearly reproduced. The key to the mammals seems workable, and is certainly most welcome.

Lastly, wildlife biologists in Alaska could well take a lesson from the University of Kansas workers who completed their field work, squeezed their data for all it was worth, and

promptly published their results. Our principal criticisms stem from the regrettably short period covered by their field work.—JOHN L. BUCKLEY AND ROBERT F. SCOTT.

Burt, William Henry. MAMMALS OF THE GREAT LAKES REGION. University of Michigan Press, Ann Arbor. Pp. xv + 246, 54 figs., 77 maps. May 31, 1957. Price, $4.75.

Having already produced books on the state and the continental level, the author now presents us with this regional guide to the mammals in the area of the Great Lakes watershed and adjoining territory, a tract covering all or part of twelve states and two Canadian provinces. To the many who have used THE MAMMALS OF MICHIGAN, the contents will be largely familiar; for this is a revision of that book, with the added treatment of fourteen species beyond the scope of the earlier work. But this is far more than a mere guidebook, for a wealth of material pertaining to mammalogy in general is packed between its covers. There has been considerable rearrangement, accounts have been brought up to date throughout, and the over-all size (5 ½ × 8 ¾ in.) represents a convenient reduction.

Treated are 81 different mammals, including 74 endemic species, four introduced species now established in the wild (the elk, European hare, Norway rat and house mouse), and three vanished species that disappeared from this area in historic times (the wolverine, mountain lion and bison). Under the species accounts are concise descriptions, weights (in grams and ounces) and measurements (in millimeters and inches), and notes on habits, habitat and economic status. Introductory matter deals with the faunal history of the Great Lakes region, economic importance of mammals, adaptive radiation (particularly in limbs and teeth), populations, home ranges and territories. Comprehensive and workable keys, largely rewritten, serve to identify all species from skin or skull; a glossary of technical terms is appended. One detailed chapter is devoted to collecting and preparing specimens. The dental formulae of all species are tabulated, and a summary presents such vital figures as measurements, numbers of teeth, toes and mammae, longevity, home range, gestation and other breeding data. There is a list of the 19 orders and 118 families of mammals living in the world today, with common names and general areas of distribution. The primates are herein relegated to a lowly position after the insectivores; the Pinnipedia is regarded as a full order; and the order Pholidota replaces the Nomarthra. A list of 129 references and a useful index are provided.

The book is liberally illustrated with black-and-white cuts. Most of the portraits (except in color) by Richard Philip Grossenheider have been retained, as well as the figures in the keys and elsewhere by the late Grace Eager; additional drawings are by William L. Brudon. The distribution maps for each species are new, showing the known range in the Great Lakes region and, as an insert, the range in North America. And here the author ventures forth in the role of artist as well as cartographer, providing on each map a small sketch of the subject, in characteristic pose, as an aid to identifying specimens to a particular group.

The emphasis throughout is on species, with only brief mention of the recognized races of eleven species which occur within this area. In the modern trend, authorities for scientific names are cited in all cases without parentheses (which, after all, are of concern only to professional taxonomists). Common names are provided in all cases and it is to be hoped that some—e.g., "heather vole" for *Phenacomys intermedius*—will gain currency. Some eyebrows will be raised at such ultra-modern terminology as shorttail shrew, hairytail mole, plainnose bats (vespertilionids), longtail weasel and yellownose vole, and the question may be asked why white-footed mouse and silver-haired bat are not treated similarly.

The book is attractively printed on good paper. Few errors were noted in the reviewer's copy, but several of the older cuts were rather badly smudged. The distinctive, durable cover enhances the usefulness of the volume. Its realistic price, made possible by a non-commercial publishing house, will be widely appreciated. The book should surpass its predecessor in popularity. Its broad appeal is to teacher and student, tourist and sportsman, and outdoorsmen generally. It is an essential reference work for mammalogists in the Great Lakes region. —RICHARD H. MANVILLE.

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COMMENTS AND NEWS

HONORARIA

Two honoraria are available each year for young mammalogists who have not obtained the Ph.D. degree. These honoraria carry a stipend of $100.00 each to help defray the expenses of travel to the annual meetings for the presentation of the paper. In 1958 the meetings will be held in Tucson, Arizona, about the middle of June. Entries should be submitted to Dr. Stephen D. Durrant, Department of Zoology, University of Utah, Salt Lake City, Utah, before April 1, 1958.

RESOLUTIONS

Members having resolutions intended for action by the Society at its next annual meeting are urged to submit them to the Resolutions Committee at the earliest opportunity. The committee is anxious to submit the proposals to the members prior to the meeting but can do so only if they receive such proposals at an early date. May 1, 1958, has been set as a deadline. Proposed resolutions should be sent to the Committee Chairman, Dr. Keith R. Kelson, National Science Foundation, Washington 25, D. C.

PAYMENT OF DUES

In accordance with the bylaws, annual dues are payable in advance for the calendar year. In future, mailing of the Journal to members still in arrears on February 10 will be suspended with issue No. 1 (February).

NOTICE TO AUTHORS

The attention of contributors to the Journal is invited to the suggestions on the following page. To those interested in typographical matters, a Style Sheet is available on request to the editor. This four-page folder contains Journal specifications, sample pages with format for tables, references, etc., and standards for spelling, treatment of numbers and abbreviations, and other matters. Please enclose a stamped, self-addressed envelope.

DEATH REPORTED

W. B. Cadwalader, May 31, 1957

SUGGESTIONS TO AUTHORS

The *Journal of Mammalogy* publishes original papers with significant new material on any phase of the science of mammalogy. While authors need not necessarily be members of the society, it is suggested that those doing serious work in this field consider carefully the desirability of affiliating with the American Society of Mammalogists.

Papers are generally published in order of receipt with some exceptions at the discretion of the editor. Papers over 20 printed pages in length are rarely published because of cost and space limitations. When subsidized, however, such papers may occasionally be published. Photographic and tabular matter, likewise, will be accepted only when necessary to the exposition of the paper and when the data or point presented are not repeated in the text.

A neat, carefully prepared manuscript is assured more favorable consideration by the editors. It also expedites processing and is more likely to appear in print as the author intended it. Toward this end, the following suggestions are offered as a guide:

All manuscripts should be typewritten on one side only of a good quality white bond paper, preferably 8½ × 11″ in size. All material—*including titles, by-lines, headings, tables, extracts, references and legends*—should be double-spaced. Carbon copies will not be accepted, nor will originals on onionskin or highly glazed paper. Pages should be numbered consecutively in the upper right corner. Tables (with captions) and the legends for figures and plates should be typed on separate pages following the text. All margins should be at least 1½″ wide. Do not mark for typography, except to indicate *italics* by underscoring.

Titles should be brief as an aid to bibliography. Usually less than ten words will suffice. Avoid citing scientific names in the title but incorporate them early in the text.

Acknowledgments and reference to sponsorship and contract number are included in the text. Avoid footnotes hung from the text. Note author's affiliation at the end of the article. This should be concise—it is intended to furnish his current address, not his biography.

References, when less than six in number, should be inserted in parentheses at appropriate spots in the text; they should include author, publication, volume, pagination and year, but not title unless a book. More extensive references, arranged alphabetically by author and with title included, are grouped under "Literature Cited." In general, our bibliographic style follows the suggestions made in the A.I.B.S. Bul., 2 (2): 21–23, 1952.

Standard abbreviations are used freely, particularly in tables and with units of measure, *e.g.*, 5.7 mm., 12 cc., 23 lb., 5 hr., 35 mph, 20°C.

Tables should be typed on separate terminal pages and should be arranged as simply as possible to fit Journal page size. It is not always necessary to present all data at hand; the author should exercise some judgment as to what data are essential. Include the units of measure employed. Do not insert rules except in box heads, and then only lightly in pencil.

Figures include black-and-white drawings and graphs reproduced as line cuts. Originals should be submitted. Some reduction is desirable, but a drawing need not be more than twice the size of the intended cut. If a scale is included, anticipate its reduction in size. Labels also must be planned to be easily legible when reduced. All lines must be solid black, not gray. Graphs may be made on paper with pale blue lines which will not reproduce.

Plates are photographs reproduced as halftones. The originals must be sharp, with high contrast, and printed on glossy paper; they should be submitted unmounted. A size of 4 × 5″ is ordinarily most convenient. Each should be identified by a light pencil notation on the back. Cropping to remove non-essential portions is often desirable.

A summary, brief and informative, is advisable at the end of major papers.

Authors are urged to consult recent issues of the Journal for examples of styling. *A Manual of Style,* Univ. Chicago Press, is a standard guide. The Government Printing Office *Style Manual* is especially helpful on capitalization. The final authority for spelling is Webster's *New International Dictionary,* unabridged. Webster's *New Collegiate Dictionary* is adequate for most purposes; it contains a useful appendix with rules for punctuation, capitalization, hyphenation, preparation of copy, and proofreaders' marks. Fowler's *Modern English Usage* is a sound and entertaining reference on grammar and writing in general.

Proof should be read word for word immediately upon receipt and returned promptly, with manuscript, *to the editor.* Errors should be corrected in the margin, but galleys are not the place for widespread corrections by the author. Essential changes or additions are best added at the end of a paragraph, or inserted as a new paragraph. Extensive changes from the original copy will be charged to the author. Cuts should be identified by number, the desired placement of tables and figures indicated in the margin and, where it is not evident, each cut should be labeled TOP on one side.

Reprints may be ordered directly *from the printer* when galleys are checked. An order form is supplied with the proof. One hundred reprints, without covers, are furnished gratis to authors of major articles, provided that at least 100 additional reprints are also ordered.

Abstracts of major papers should be prepared and returned with corrected proof.